# Pulverised-Fuel Firing for Metallurgical Work

***The use of coal in pulverised form offers many definite advantages and has wide applications.***

THE national advantages of pulverised fuel firing for metallurgical work are not clearly recognised in this country, although in America, and in Germany especially, the system is being increasingly employed. There are naturally very many circumstances to which the metallurgist must give careful thought when contemplating any departure from heating conditions as they may exist on his particular furnaces, the most important being the effect that any such new method may have on his product.

*Fig. 1. Battery of Ovens for Annealing Castings.*

In Great Britain, where very many works produce from their furnaces specialised products, it is perhaps understandable that there should be considerable caution exercised before any radical change in fuel application or furnace design is made. The unqualified proof of fuel economy and a reduction of other operating charges consequent upon the application of pulverised fuel to metallurgical furnaces, in foreign and competitive countries, is incontrovertible.

Whilst admitting that the exploitation and adaptation of pulverised fuel to the metallurgical industry have made great strides in U.S.A., the fact should not be lost sight of that many and diverse classes of furnaces have been applied in this country, and the experience which is here being built up is undoubtedly based upon the secure foundation of steady and careful progress.

Apart from direct fuel economy consequent upon the utilisation of coal in pulverised form, other very definite benefits frequently more than offset the extra cost of pulverisation, and the collective value of these are so much the greater gain. These include considerable reduction in metal losses due to oxidation; greatly increased furnace output (15 to 25%); accurate control of temperature; a greater degree of heat penetration, making for less wear on rolling-mill equipment and machinery; elimination in the cost of transporting raw fuel from one furnace to another; the almost complete abolition of stoking tools; the reduction in labour charges due to the changed furnace conditions.

Without any doubt, therefore, there exists to-day ample proof to guarantee results advanced in moderation; although it will be understood that whilst the general economies under this system of firing would be present in nearly all works, other details would be consequent upon various circumstances which may be peculiar to any given works or site.

Many records are available relative to the countries referred to, covering a period of years, for reheating furnaces, soaking pits, bushelling and faggoting furnaces, sheet and pair furnaces, heavy and light forge furnaces, and, in particular, puddling, malleable-iron melting, and annealing.

The number of American pulverised-fuel installations at metallurgical works, both for furnaces and boilers, is now approximately 300. Several of these larger plants, most of which are of the central-system type, have cost over £100,000, and in the majority of smaller works between £30,000 and £50,000.

In one instance the cost of the plant, namely £112,000, was repaid by savings effected within two years. At another American works, a sheet and tinplate mill, the entire fuel consumption, including that for steam raising and auxiliaries on the first year's working, amounted to 500 lb. of coal per ton of sheets produced, a clear cut of 50% over their previous practice.

It is estimated that between 15,000,000 and 20,000,000 tons of coal in pulverised form are now used per annum in American metallurgical works, resulting in an all-round annual saving of at least 20% in fuel; the utilisation of great quantities of inferior fuel in place of high-grade coal; 30 to 50% reduction in labour costs as against hand-firing; and incidental economies in other directions.

It is difficult to give an accurate estimate as to the total annual value of such collective savings in the iron and steel industries of America. It is certain that these represent many millions of pounds sterling, a national economy which has placed production costs upon a most favourable basis. It is for this reason that the effect of equivalent economies upon British production costs should be studied. Perhaps the greatest measure of success has been achieved in the application of pulverised fuel to malleable-iron melting and annealing furnaces, to puddled-iron furnaces and reheating furnaces.

*Fig. 2. The application of Pulverised Fuel for Melting Malleable Cast Iron.*

The return on capital at malleable ironworks has been as high as 80% per annum, and the average saving in fuel alone 30%. It has been established that an overall saving of 8s. to 10s. per ton of iron melted and annealed is readily obtainable, and increases in the life of annealing boxes up to double the life previously experienced.

The value of this system to the malleable-iron industry

is such that one pulverised-coal machinery supply company has concentrated almost entirely in this direction, and has equipped over 30 of the the great American ironworks with this method of firing. Malleable ironworks in France have also been equipped, and the following results have been recorded with pulverised fuel from unit machines.

The temperature of annealing furnaces can be raised within 2 hours to 700° C., being slowly increased during the next 16 hours to 870° C., and maintained constant at

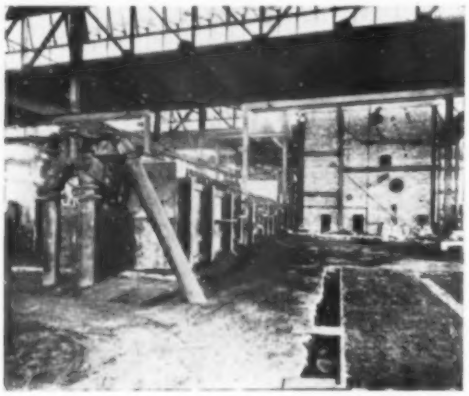

*Fig. 3. Larger capacity furnace for Malleable Cast Iron fired with Pulverised Fuel.*

that temperature for the remainder of the annealing period of 56 hours. The fuel consumption, using slack coal, is 38% of the charge, the coal costing 135 francs per ton, as against hand-fired fuel costing 220/250 francs per ton; the overall saving in cost of fuel being 75%, or 173 francs per ton of iron annealed. It will be appreciated that annealing conditions are not always the same, as the cycle of operations varies in certain works, but the same proportionof economy can be expected in nearly all circumstances. Fig. 1 shows part section of a battery of 15 annealing ovens which are supplied with pulverised fuel from a circulating system which can be seen overhead. A single burner is employed in each of these ovens, which have a 20-tons casting capacity. The coal and air connections can be clearly seen above the burner. The temperature of the ovens runs at 950° C., and the cycle of temperature averages about 76 hours. One man looks after this whole battery.

With regard to melting for malleable-iron castings, the

*Fig. 4. Central Pulverised Fuel Equipment.*

economies are to be looked for in the fuel saving and in the time which is required from charging the furnaces to the time of tapping. The practice commonly employed is to run two heats from each furnace per day, the first charge being in a cold furnace would, naturally, require an increased fuel ratio, the figures from one works being on a 20-ton furnace, 15–18 minutes per ton of charge-melting time, and a ratio of 2·95 tons of metal to 1 ton of coal burned; on the second heat the melting time is from 12–15 minutes per ton, and the ratio is between 3·22 and 3·28 tons of metal produced to 1 ton of coal burned. On larger 30-ton furnaces the fuel ratio is from 3·57 to 4 tons of metal per ton of coal. An illustration, Fig. 2, shows the application of pulverised fuel to an air furnace for melting malleable. The capacity of this furnace is 12 tons of metal, and the pulverised-fuel burners can be seen on the right; the coal and primary air from above, and secondary air through the vertical pipes from below. Fig. 3 shows a similar type of furnace of a larger capacity with a Stirling waste-heat boiler on the right. The capacity of this particular furnace is 25 tons of molten metal, and the capacity of the boiler when running from one furnace of this size is about 20,000 lb. of steam. The coal system in this case is from a central point, and the coal-conveying main, which can be seen coming up through the ground and delivering into the top of the burners, secondary air being again from below.

Under hand-fired conditions these furnaces would produce the same tonnage of metal, but the ratio would be between 1·6 to 2·1 tons of metal per ton of coal. The time element for melting is also a variable feature with regard to hand-fired furnaces, and the slightest variation in the coal would mean that the furnaces may be set back and the tapping period consequently made later, such a condition tending to increase production costs in a works for moulders' overtime and in general disorganisation which late tappings would cause.

## Regulating Furnaces to a Schedule.

Under pulverised-coal conditions the charging, firing, and tapping of the furnaces can be absolutely regulated to a definite schedule, which in itself is a great asset to the smooth running of any foundry. It should be pointed out that in connection with melting furnaces of this type fuel containing a high volatile becomes almost essential, so that, in this instance, the cheaper low-grade fuels would not usually be applicable.

The normal consumption of fuel for hand-fired, puddled-iron furnaces is about 3,000 lb. of coal per ton of muck-bar produced. Similar coal, when applied in pulverised form, has produced the same metal weight on a consumption of 1,800 lb. per ton. Figures compiled show that fuel consumption per ton of muck-bar produced has been as low as 1,200 lb. It can safely be taken, therefore, that a saving of 40% in fuel over hand-fired conditions can be effected and maintained in this type of furnace. In addition to this, heats are quicker and more uniform, and the puddled iron can be worked up with more speed, giving a greater output from the furnace. One more heat per shift can be obtained. Under the old conditions the time required for heats is usually from 2–2½ hours. Under pulverised conditions this is reduced from 1½ to 1¾ hours.

Pulverised coal, as applied to blast furnaces for iron smelting, has not reached any definite stage. Experiments have, however, been made, and a reduction in metallurgical coke of 10 to 12% effected by the introduction of pulverised coal with the charge and as an auxiliary firing medium; but the application has been attended by considerable difficulties at the burners, although it would seem that the troubles experienced will in the future be entirely overcome.

A greater measure of success has been obtained in the use of this fuel as auxiliary firing for cupolas, 30% reduction in coke having been effected, the respective quantities of fuel used in relation to the charge of iron being 1% pulverised coal to 7% metallurgical coke. Other advantages are also realised, such as increase in the cupola output of 25 to 40% and a hotter casting metal. The foregoing results have been obtained in Germany, and reports from France also confirm the satisfactory nature of this application. Fig. 4 shows a central pulverised-fuel equipment, and raw-coal storage silos at a large English foundry. The

raw-coal silos accommodate 700 tons of stock. The pulverising building is seen on the right, and serves from this one point melting furnaces, coke ovens, etc.

At an iron foundry in France, a small-unit installation originally installed for producing "Foundry blacking" has been utilised for augmenting cupola firing with pulverised coal. The cost of the raw coal is 140 francs per ton, metallurgical coke being 214 to 250 francs per ton, and the relation of fuel to metal charge is 2% of coal and 4·5% of coke, showing a normal saving in cost of fuel of 11 francs per ton of iron smelted. The increase in cupola output is 50%, a reducing heat is maintained throughout, and sulphur contamination is considerably less than that of coke firing.

In non-ferrous blast-furnace work pulverised coal has been successfully applied in the production of nickel and copper. In the former case coke consumption has been reduced from 40% to 50%, and for copper production pulverised coal alone has been used, the ratio being 3·8% of coal in place of 6% of coke.

The most astonishing economies in non-ferrous operations are evidenced by the present-day general practice of firing open-hearth reverberatory copper-smelting furnaces with pulverised coal. The furnaces at the Canadian Copper Co.'s works, for instance, after conversion from hand firing to pulverised-coal firing gave approximately a double output at half the fuel consumption, the figure being, for hand firing, 250 tons of copper per 24 hours, and 3·8 tons copper per ton of coal. Pulverised-coal firing gave 475 tons of copper per 24 hours, and 7 tons of copper per ton of coal. In these and all heavy metallurgical applications the system of production and transportation of the fuel is usually "Central-mill" plant, the daily tonnage being sufficient to render central pulverisation advisable, and the retention of fuel in reserve bunkers a matter both of convenience and caution. Fig. 6 shows one type of heavy-grinding pulveriser which is utilised with central systems. For large works this method enables coal supplies to be concentrated at one point and eliminates fuel wagons and local distribution costs, the latter representing as much as 2s. 6d. per ton in some recorded instances. This saving in itself may cover the cost of pulverisation in specific cases.

*Fig 5. Continuous billet-heating furnace with a Pulverised Fuel Combustion Chamber.*

The previous requirements that coal must be dried to below 5% free moisture prior to pulverisation no longer applies in the generality of cases for the small-unit machines. For the most exacting operations, however, of small nut and bolt furnaces, light-forge furnaces, rivet-heating furnaces, and high-temperature work in both large- and small-combustion areas, and for special purposes the drying-out of moisture in the coal is still necessary.

The more confined the combustion area the greater must be the degree of uniformity and fineness of the fuel, and the more perfect the intermixing of the fuel with its air supply prior to combustion. The imperfect mixing of fuel and air can only be entertained in the admittedly crude applications, such as water-tube boiler firing, the burning of cement, etc., but for metallurgical work the greater the degree of mixing the better will be the results.

Burners embodying such principles are now available whereby dispersive or diffused projection ensures complete combustion within a comparatively short distance of the burner orifice. In such circumstances alterations to existing furnace settings are slight, but faulty mixing and incorrect method of applying the fuel and air necessitate special and costly combustion chambers.

Progress in the knowledge of pulverisation and methods of obtaining short-flame combustion have greatly overcome the heavy expenditure previously attributed to pulverised-fuel firing, particularly as regards combustion-chamber reconstruction. It is to be expected, therefore, that metallurgical engineers in Great Britain will, for small installations, give their close attention to the results now obtainable with the self-contained unit equipment. The mill or pulveriser of such unit plants should in all cases be of a type to actually grind the coal and to maintain a fine and uniform product at all times.

The two principal objections usually advanced against the use of this system are inflexibility and high cost of maintenance. Both these circumstances being, to a very great extent, dependent upon the type of machine, the grade of fuel, and the nature of the application. For rapidly fluctuating loads, unit machines, unless specially designed, may reasonably be unsuitable for power production, but for metallurgical operations this objection hardly applies. Reliable records of maintenance costs have shown a figure as low as 1d. per ton of pulverised fuel produced, and as high as 1s. 2d. per ton. A normal and rational cost for maintenance of unit-machine equipment installed should certainly not exceed 3d. or 4d. per ton when using the usual grades of bituminous coal. Anthracite and hard fuels will raise this cost to, say, 6d. or 8d., and for gasworks coke alone to 8d. or 1s. per ton, according to the type of pulveriser unit.

The unit pulveriser should not be called upon for the breaking-down stage of hard lump coal. Hard lump coal should be precrushed between slow-running rollers, and the fine pulverisation stage only accomplished in the grinding unit. Maintenance cost of the latter must then be a fraction of that occasioned by the whole grinding and crushing operation. Fig. 7 illustrates a unit-type Kennedy ball mill for application to either metallurgical furnaces or boilers. The fan, seen on the right of this photograph, is the point of discharge for the fuel direct to the burners on the furnace. Secondary air connection is adjacent thereto for short circuiting, the air quantity being drawn through the mill, also for the reception of hot air when such may be available from waste heat sources.

A typical instance of self-contained units installed at a British works involved the conversion of preheating furnaces from hand-firing to pulverised-coal firing. The

furnace is 35 ft. long, and is used for heating large plates up to $1\frac{1}{2}$ in. thick. It was originally fitted with side grates, but is now fired at the two ends only. It previously took 24 hours to heat the furnace to the required temperature, a period in which 3 to 4 tons of coal were burned. The furnace can now be heated up in 2 hours with 25 cwts. of pulverised coal. For damping-down the furnace over-night, between 20 and 30 cwts. of coal were burned under the old conditions. This cost has now been entirely eliminated. The scaling loss, due to inefficient firing conditions, has been reduced to a negligible figure. Plates are more thoroughly and uniformly heated and require less time and power for pressing. Regulation of temperature at all times is under perfect control, and the dust covering on the plates is readily blown or brushed off before rolling.

*Fig. 6. Heavy-grinding Pulveriser associated with central system.*

In another works the heating of heavy-forge furnaces shows a reduction from 800 lb. and 900 lb. of coal, respectively, per ton of metal to 600 lb. and 700 lb. of similar fuel in pulverised form.

On a large continuous-billet-heating furnace at another steelworks carefully compiled figures over a week's run gives the production of metal at $241\frac{1}{2}$ tons, with a consumption of 40 tons of pulverised coal of cheap bituminous slacks. This was produced in 80 hours' operation and gives a ratio of 3·32 cwts. of coal used per ton of steel heated, a reduction of 40 per cent. over hand-fired conditions. For smaller billet-heating furnaces a reduction from 800 lb. of fuel to 400 lb. has been achieved. Sheet and pair furnaces show at least a 25% reduction in fuel used, and the loss due to stickers and defective plates is less by 25%. The capacity of the sheet rolls is also augmented by 15%, due to the softer degree of heat penetration. Normal fuel consumption is in the region of 220/250 lb. of 12,000 B.th.u. fuel per ton of plate rolled.

The illustration, Fig. 5, shows a continuous-billet-heating furnace with the pulverised-fuel combustion chamber on the right. The output of this particular furnace was increased 25% after the installation of the pulverising equipment, with a fuel output of 30% less than under hand-firing conditions. The combustion chamber was enlarged particularly to eliminate as much ash as possible from being passed to the product, because the billets in this case are all high-class.

At another steelworks in Great Britain gas-heated regenerative furnaces for reheating and bushelling were converted to pulverised coal. The only change made in the complete furnace structure was to close up the gas-production section and to enlarge the apertures through the generative chambers. The operation of the secondary air was retained exactly as before, the results of economy being 17% in favour of the pulverised fuel, and this when using a grade of coal costing 14s. as against 23s. under hand-fired gas-producing conditions, in addition to which the labour reduction was in excess of the monetary value of the fuel saved.

The reheating of billets and blooms for rail rolling is effected with a consumption of 100/150 lb. of similar coal, as against previous hand-firing figures of 450/550 lb. In Germany this operation is being accomplished with the utilisation of 150 lb. of brown coal.

Furnaces for copper reheating and annealing are also successfully applied in this country, and actual figures from a series of furnaces gave a coal consumption of 170 lb. of coal per hour for the smaller furnaces up to 400 lb. of coal per hour on the large furnaces under hand-firing conditions. The reduction of fuel consumption under pulverised-coal firing was 27% in the former case, and in the case of the larger furnace 28·5%, the fuel used being of a cheaper cost—*i.e.*, 17s. as against 24s.

Ash and slag troubles do not appear to produce any serious difficulties to-day. Slag in combustion chambers is now readily removable in solid form for low-temperature operations, and in a fused or liquid state from high-temperature chambers. The actual ash deposit on work heated or brought to a temperature approaching fusion offers no great difficulties. In the former case, for instance, the ash deposit is of a very fine dust character, and is readily blown or brushed off the plates before rolling. In piles and faggots the fused slag cracks off in the first pass of the rolls, and no trace is found thereafter, the iron being particularly free from bad spots.

For exacting operations good-quality coal is essential. Low-grade fuel, high in ash and low in price, can undoubtedly be used extensively throughout a works, but results will carry the cost of a better-quality coal when it is remembered that a direct saving of 30% in fuel consumption is being effected, and other advantages of perhaps equivalent value. Cheap coal is not always the most economical for many metallurgical applications, and it should be remembered that whatever dirt is in the fuel to begin with requires power to pulverise it, and it also costs money to eventually dispose of it. This, too, is irrespective of any consideration as to the effect of ash on refractory surfaces and the maintenance of furnace conditions generally.

There is doubtless much to be gained by a scientific study of the fuel to be used in relation to the operation. Coal blending in many cases is advantageous, and in time to come greater use will undoubtedly be made of by-product or residual fuels. Semi-coke from low-temperature distillation centres will become of increasing importance. It has only been possible to touch upon the fringe of the possibilities of pulverised fuel in its application to metal production in its various forms, but the obvious advantages which accrue from this method of fuel utilisation cannot be neglected. Cheaper production costs are of first importance in the metallurgical field and fuel must largely enter into such calculations.

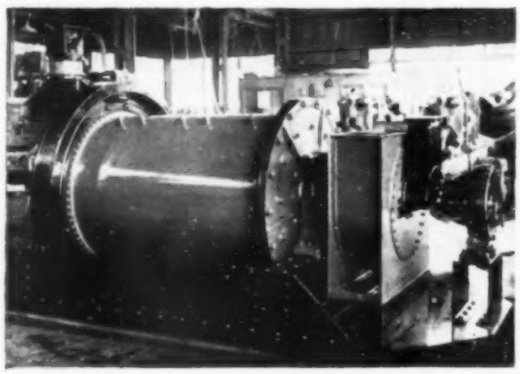

*Fig. 7. A unit-type Kennedy Ball Mill.*

This is but touching upon the average of the possibilities which attend the general reduction of fuel costs through the metallurgical industries, and in no way can those great benefits be more rapidly introduced than by an acceptance of the constructive working results in evidence through the world.

# Modern Steel Pouring Practice

By K. R. Binks.

INGOT moulds are of many diverse sizes and shapes, and in a works of moderate size a dozen varieties may be found of three or four characteristic types. Many of the newer designs were intended to eradicate or counteract such defects as piping and axial weakness in the ingot, others to offer increased resistance to the tearing of the ingot corners during rolling down. It became apparent from the first that thickness of the mould in relation to the cross-section of the ingot had a definite bearing on the proportion of dendrites in the ingot, and hence on the tendency of the ingot to fracture in planes at right-angles to its axis when under pressure in the rolls or forging press. It can be seen, of course, that the only means for the body of the ingot to lose heat immediately after pouring is through the capacity of the walls of the mould to absorb it, and since the dendrites are produced by crystalline growth at right-angles to the mould walls, their growth could be limited by thin-walled moulds.

The question of the loss of heat by radiation from the exterior of the mould does not become prominent until the mould walls are sufficiently heated up to dull-red heat by their own cooling effect on the ingot.

## Relation of Length to Cross-section.

The relation of length to cross-section has a great effect on axial weakness in the ingot, for, where this ratio is large, the lower portion is apt to be spongy in the centre, due, no doubt, to the contraction of the final portion to solidify, the general cooling of the ingot being fast enough to prevent feeding of the lower centre sections. The weakness so produced becomes apparent as hollow centres in material after cold-drawing. Where the mould is designed with shorter length and marked increase in cross-section the slower cooling of the interior of the ingot produces equiaxed crystals in zones of pronounced difference in composition, thus giving rise to apparently haphazard variations, which though small in themselves are noticeable on sectioning the ingot.

The size of mould to be utilised has distinct influence on the degree of segregation and proportion of piped material. It is now common knowledge that an ingot of, say, ten tons weight under the same conditions as an ingot of four tons weight is much more liable to these defects and necessitates increased cropping of the waste material. Modern practice now essays to combine the three factors of length, size, and thickness of mould walls in order to produce the best possible ingots.

In the earlier days of steel-making, moulds were made with smaller cross-section at the top in order to facilitate stripping of the ingot. Consideration soon showed that since freezing of the ingot proceeded at right-angles to the walls of the mould, there must come a stage in the solidification when no further feeding of the lower centre portion would be possible. This accounted for the extensive pipe sometimes found in this type of mould design, and necessitated the casting of better-class material in wide-end-up moulds. The piped portion was thus confined to the top of the ingot. Increased knowledge then suggested the further retardation of the cooling of the ingot top by means of a refractory head, which then brought the piped material outside the usable part of the ingot.

In etching the earlier sections of ingots teemed into open-bottom moulds on heavy cast-iron "stools" or bottom plates, the marked growth of dendritic crystals from the bottom plate was noted. They appeared in the shape of a truncated pyramid, whose height depended on the temperature of the steel and the cooling power of the cast-iron bottom plate, and they were somewhat obviously influenced in growing by the crystalline growths from the mould walls. Definite lines of weakness were noted at the junctions of the two systems of crystallisation, and in one or two extreme cases the plug so formed by the pyramid of crystalline growths was forced out of the ingot in the subsequent rolling down. To obviate the sharp demarcation thus produced, the use of closed-bottom moulds with radiused corners became general, and, owing to the stripping problem, were embodied in the wide-end-up type.

## Production Per Mould Varies.

The number of ingots that may be made from one mould without the production of surface blemishes varies considerably. Best quality iron is necessary. West Coast hematite is extensively used for the purpose, and careful work should produce sound and clean castings with an interior surface free from warpage and blowholes. The cores should also be carefully inserted in the boxes or the resulting unequal thickness of the mould walls will cause distortion and ultimate cracking when teemed into.

The composition of the iron used should have careful thought, for apart from its influence in the iron foundry, silicon in even moderate quantities favours the graphitisation of the iron under the repeated heating of the mould in use. To a large extent the increased life of mould obtained under the car-casting system as against the older method of teeming into moulds set in a sunken pit may be ascribed to the fact that in the former system the moulds do not attain a temperature high enough for graphitisation to proceed far. After several heats of steel, the interior surface of the mould shows signs of wear and oxidation, and then in many cases receives treatment with brushes and mould paint. This prolongs the useful life of the mould and produces an ingot having a much cleaner surface.

Among moulds of chiefly academic interest is that described at a recent meeting of the Iron and Steel Institute, in which advantage is taken of the beneficial effects of freezing-in the ingot from bottom upwards. Steel is cast into a mould of large cross-section and short length, having refractory sides and a heavy cast-iron bottom plate. In these circumstances cooling proceeds mainly through the bottom plate, and the effect is accentuated by the use of gas jets burning in the closed top of the mould.

The ingot so produced does show a minimum of pipe, axial weakness, and confines the segregate to the upper regions of the ingot, but the time taken in cooling down and the unwieldy shape of the ingot are disadvantages where large outputs are concerned. The effect of very slow cooling on the non-metallic inclusions is marked, many of the coalesced particles attaining a large size. The elimination of these inclusions in the ordinary type of ingot for use in the rolling-mill has received attention in many technical papers since the microscopical examination of steel became general. They were invariably found to be sulphides of manganese or iron, silicates, or entrapped refractory material, and their probable composition suggested that they were most likely secondary products formed from the addition of the killing agents to the ladle. Two methods were then developed to eradicate their presence, the first by adding the "finishings" to the furnace before tapping, the inclusions then rising into the covering slag, the other by adding a titanium alloy to the ladle of liquid metal and allowing time for the then more fusible inclusions to rise out of the steel. The former method is now generally used, and for the elimination of refractory material which may have got into the mould vacuum cleaners are installed.

As may be readily imagined, a column of liquid steel falling into an empty mould reaches the bottom with considerable energy, which is absorbed in the rebound

(*Continued on page* 66.)

# Some Metallurgical Problems Connected With the Possible Use of Very High Steam Temperatures.*

By J. H. G. MONYPENNY, F.INST. P.

## Part II.

IN the first part of this article, the effects of high steam temperatures on the properties of steels, more particularly with regard to their strength when continuously loaded at such temperatures, were discussed in a general way; in the following paragraphs it is proposed to consider some of the special difficulties encountered in two particular types of high-temperature steam equipment.

Superheater tubes are likely to provide the engineer with one of the most difficult problems in the use of very high steam temperatures, because the steel is here in contact with the steam at its highest temperature and pressure. Mild-steel tubes have been used successfully for temperatures of 400°/450° C. (750°/840° F.), and probably the use of a low-carbon nickel steel—as at Mannheim and Issy-les-Moulineaux—will give a greater factor of safety at these, or slightly higher, temperatures. Apart from any other consideration, however, the chemical reaction between such steels and steam at temperatures of 900° F. and over sets a limit to their use; for still higher temperatures, more chemically resistant steels must be looked for. Bearing in mind the fact that any selected material must be producible commercially in the form of seamless tubes, the possible alternatives appear to be stainless iron and the austenitic chromium-nickel steels of the "Anka-Staybrite" type, neither of which are sensibly attacked by steam at temperatures below about 1200° F. (650° C.).

Consideration of creep stress in this case introduces another factor. If a steam temperature of 950° F. be assumed, what is likely to be the temperature of the super-

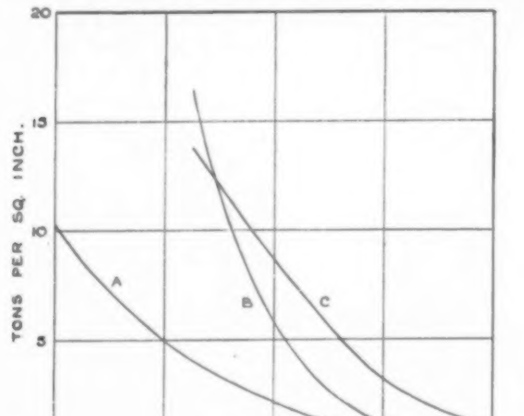


*Fig. 8.—Creep Stress Values of Various Steels. (French, Cross and (Petersen.)*

| | C. | Cr. | Ni. | Cu. |
|---|---|---|---|---|
| A. ...... | 0.24 | — | — | — |
| B. ...... | 0.28 | 20.5 | — | 0.98 |
| C. ...... | 0.24 | 18.1 | 23.3 | — |

heater tubes themselves? Professors Mellanby and Kerr estimate the temperature of the radiant-heat-metal surface of such a tube to be 140°/150° F. above that of the steam. Even higher estimates of this temperature difference have been made by other authorities. However, Mellanby and Kerr's estimate gives a temperature of about 1100° F. (say 600° C.) for the outer surface of the tube—that part of the tube, it should be noted, where the greatest stress arises. Incidentally, this also brings to notice a further requisite in the tube material; it must resist oxidation by the flue gases when heated to this temperature, and it may be noted that the stainless iron and the austenitic

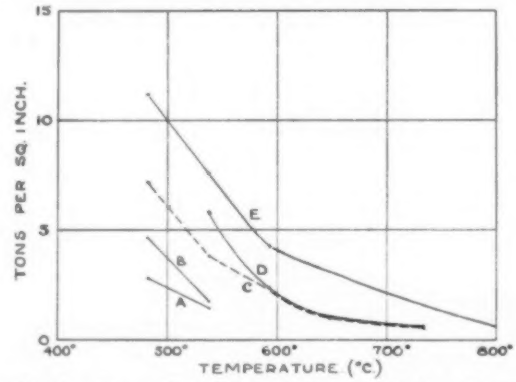


*Fig. 9.—Creep Stress Values of Various Steels. (Norton.)*

| | C. | Cr. | Ni. |
|---|---|---|---|
| A. .................... | 0.08 | — | — |
| B. .................... | 0.20 | — | — |
| C. .................... | 0.10 | 17.6 | — |
| D. .................... | 0.11 | 13.2 | — |
| E. .................... | 0.09 | 18.1 | 8.1 |

steel are both satisfactory in this respect. Thus, Fig. 10 gives the results of scaling tests carried out on samples of stainless irons; these were heated in a gas-fired furnace of such design that the samples were surrounded by the burning gas and its products of combustion. The results indicate, as would be expected, that resistance to oxidation increases with chromium content, but that 12% is ample for temperatures of the order of 600° C. The austenitic steels give results of the same order as the stainless irons of similar chromium content.

Turning now to the question of creep stresses, the values given in Figs. 8 and 9 indicate that stainless irons with 13%, 17%, and 20% chromium have creep-stress values of the order of 2—2¼ tons per sq. in. at 600° C. In both diagrams austenitic steels are shown to have higher values (3—4 tons per sq. in.), though that referred to in Fig. 8 is hardly relevant to the particular point at issue, as, so far as the writer knows, this steel is not yet commercially produced in seamless-tube form.

It would appear from Fig. 9 that there is no advantage in increasing the chromium content of the stainless iron beyond 13/14%. The same tendency is noticeable in the results given in Fig. 11. These tests were not sufficiently prolonged to enable one to form an estimate of the limiting creep stresses of the materials tested, but there is evidently a definite falling-off in strength in the 20% chromium iron. The 13/14% chromium iron is also much superior to those of higher chromium content on the score of mechanical properties.

The austenitic chromium-nickel steels would seem from Fig. 9 to possess an advantage over the stainless irons from the point of view of creep-stress values. There appear to

* *Continued from page 25 in the May issue.*

be several features about these steels, however, which require further investigation before their use under the conditions set out (*i.e.*, for tubes functioning at about 600° C.) can be recommended. It has been shown[11] that reheating these steels in the range 500°/900° C. causes a

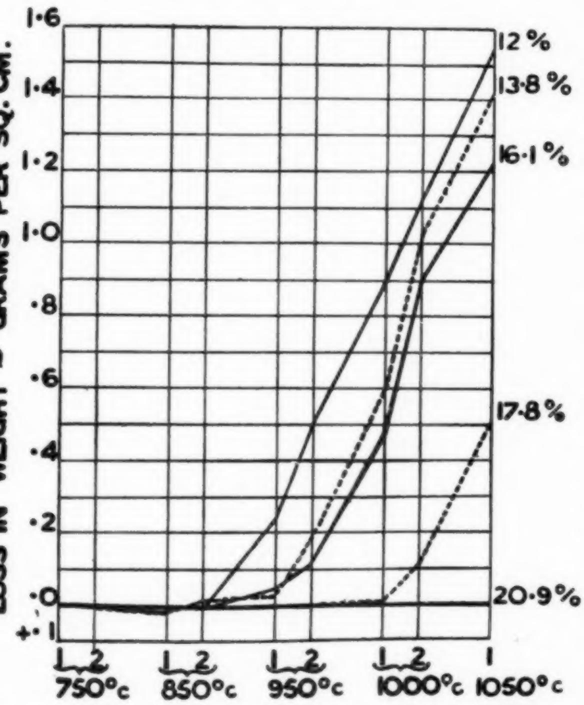


*Fig. 10.—Scaling Tests on Stainless Irons; chromium content as indicated. The samples were exposed for periods of 24 hours each at the temperatures named.*

precipitation of carbide to occur round the austenite grains, and that in this structural condition the steels are particularly prone to intergranular attack by many corrosive media which have little or no action on them when they are in a correctly treated condition. This action has been responsible for many failures in structures of these austenitic materials, principally welded ones. Further, there is evidence that austenitic steels, both of this type and of others more highly alloyed, may fail by the development of intergranular cracks when they are held at rather higher temperatures than are here considered, while being stressed continuously under loads

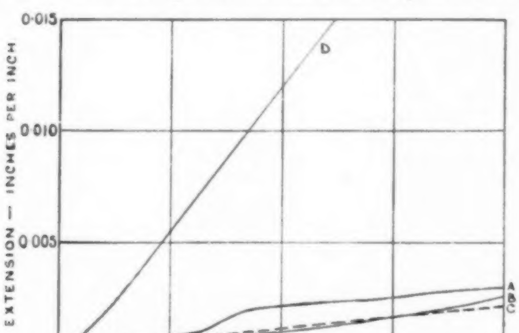


*Fig. 11.—Creep of Stainless Irons at 600° C. and $2\frac{1}{2}$ tons per sq. in.*

| | A. | B. | C. | D. |
|---|---|---|---|---|
| C ....... | 0·10 | 0·09 | 0·07 | 0·11 |
| Cr ....... | 12·7 | 14·1 | 17·1 | 20·5 |

which produce only very slow rates of creep. Moreover, this occurs in the absence of any corrosive action other than that of oxidation by hot air. For example, Tapsell and Remfry[12] showed that material containing 0·46% carbon, 14% chromium, 26·5% nickel, and 3·5% tungsten developed intergranular cracks at 700° C. and 800° C. during the course of creep-stress determinations. Specimens at 800° C. actually fractured in 73 and 152 days, after extending not more than 2%. The writer has also found a similar phenomenon in steel containing 0·18% carbon, 16·5% chromium, and 10·8% nickel when loaded at 700° with 2 tons/in². In this case the test piece broke after three weeks, the fracture being completely intergranular, as shown in Fig. 12. Prior to fracture the test piece (2-in. gauge length) had extended less than 0·001 in. One may also note in Fig. 12 the carbide network round the austenite grains. While, therefore, there is no example on record, so far as the writer is aware, in which intergranular attack has been brought about by contact with superheated steam, nor of actual fracture due to long-continued loading at about 600° C. (nor incidentally does he know of any tests of sufficient duration at this temperature on which an opinion could be based as to whether or not fracture is likely to occur), he would suggest that the employment of the austenitic steels for superheater tubes, where temperatures of the order of 600° C. may be reached, is not to be recommended until further evidence as to their behaviour under such conditions has been obtained. Such evidence should be looked for by means of prolonged tests, which will enable the effects of high temperature, continuous load, and contact with steam or furnace gases to be tested separately or together.

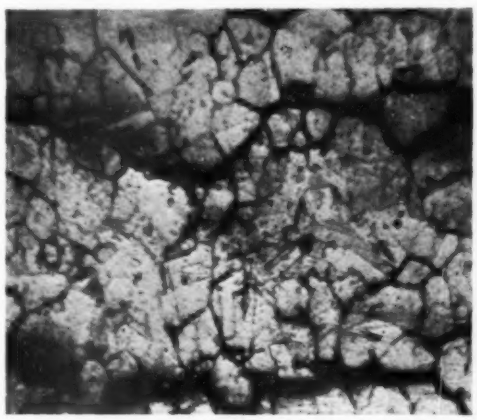

*Fig. 12.—Intergranular Cracks in Test Piece of Austenitic Steel (0·18% C; 16·5% Cr; and 10·8% Ni) after three weeks' test at 700° C. under load of 2 tons per sq. in. × 100.*

It would appear, therefore, that what hopes there are of producing superheater tubes for working under the temperature conditions postulated, lie with the chromium irons, or mild chromium steels, containing 13/14% of that metal, and the available data suggests that the maximum stress to which these may be subjected is at the most 2 tons/in². at 600° C., and $3\frac{1}{2}$ tons/in². at 550° C. Considerations of factor of safety would, of course, reduce these loads for practical applications.

Superheater tubes and their fittings are not the only problem confronting the engineer in the use of higher steam temperatures. There are many parts (*e.g.*, bolts) which do not necessarily come in contact with steam, but which might reach a temperature of 400° or over, and are required to possess, at that temperature, greater strength than may be expected from mild steel under similar conditions. The use of ordinary alloy steels suggests itself, and values obtained—*e.g.*, by Pomp and Dahmen, and by French and his co-workers—indicate that such steels are appreciably stronger at 400°/450° C. than mild steel. Their projected use, however, brings up another serious difficulty, namely, embrittlement through long-continued heating at these temperatures.

Most engineers are now familiar with the phenomenon of temper brittleness in ordinary nickel-chrome steel, that unpleasant form of brittleness which is manifested in such steels when they are slowly cooled from tempering heats, and is actually produced during the sojourn of the heated steel in a range of temperature which is approximately 400°/550°, but might conceivably extend to somewhat wider limits under the effects of very prolonged exposure.

Although the phenomenon of temper brittleness is mostly noticeable in nickel-chrome steels, it is present in a greater or less degree in many alloy steels, and hence deserves the engineer's attention. It is little use making a bolt or other part of tough material with an impact value of 50 or 60 ft. lb. if, after the course of a few days, or maybe weeks, its impact value drops to less than a tenth of this value. To obtain evidence on this question, samples of different steels were first heat-treated to put them in their toughest condition, and were then held for various periods at 400°/450° C. Their impact values were then determined, the results being plotted in Fig. 13. These show the very notable embrittlement which occurs in well-known types of alloy steels, and also the striking superiority of nickel-chrome-molybdenum steels in retaining their toughness under these conditions. The latter feature is not altogether surprising in view of the fact that such steels are known to be practically free from the effects of temper brittleness.

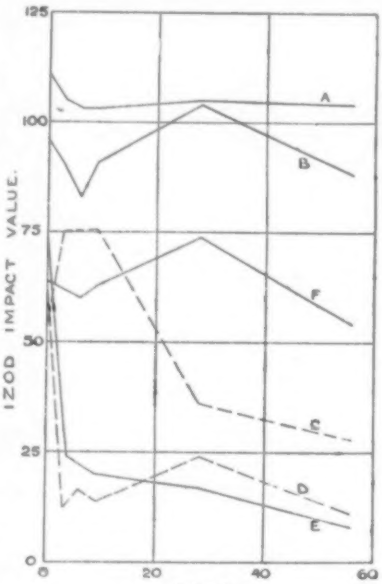


*Fig. 13.—Effect of Prolonged Heating at 400/450° C. on Impact Value of Various Steels.*

| No. | C. | Cr. | Ni. | Mo. |
|---|---|---|---|---|
| A. | 0·13 | — | — | — |
| B. | 0·31 | — | — | — |
| C. | 0·34 | 0·07 | 3·10 | — |
| D. | 0·31 | 0·10 | 4·77 | — |
| E. | 0·32 | 0·99 | 3·02 | — |
| F. | 0·37 | 0·81 | 2·63 | 0·43 |

These two examples indicate the difficulties which confront the engineer when, in his efforts to obtain greater efficiency in power plant, he has to turn from mild steel to some other material having greater strength at high temperatures. In addition, in mild steel he has possessed a material which is singularly adaptable to fabrication processes, and, in particular, is remarkably "foolproof" in its properties. It is hardly conceivable that any alloy steel will possess these features in so great a degree, and hence it is likely that the fabrication of such alloy steels as prove to be most suitable for selected parts of high-temperature steam plant, will require considerably more care, and involve greater difficulty in processing, than is the case when mild steel is the metal employed.

---

The President of the Board of Trade has appointed Alderman E. B. Lewis, J.P., President of the National Chamber of Trade, as an additional member of the Committee recently set up under the chairmanship of Lord Chelmsford, to examine the present situation as regards the British Industries Fair, and to consider what means can be adopted to increase still further its utility to British trade.

11 "Corrosion-resisting Steels and Their Applications," "The Iron and Steel Industry," February, 1930, p. 149.

12 "The Creep Strength of a High-Nickel-High-Chromium Steel between 600° and 800° C." D.S.I.R. Report No. 5.

# THE EFFECTS OF SILICON ON THE PROPERTIES OF BRASS.

CONSIDERABLE research work has been accomplished in estimating the effects of tin, aluminium, lead, manganese, iron, and nickel on copper and brass, but relatively little work seems to have been done on the effects of silicon on brass. Vickers stated that 4% silicon added to ordinary yellow brass, with with no lead present, gives very tough ductile castings which resemble manganese brass in appearance. When the zinc content is increased to 40%, the addition of 2% silicon produces similar effects, the tensile strength being stated to be over 21 tons per sq. in. The effects of silicon are similar to those of aluminium, except that the alloy casts better and contains less dross.

A study of the subject was thought advisable in order to check available data, to determine the various properties over as great a range as possible in the time available, and to correlate these properties with the metallographic constituents of the same alloys. This study has been made by H. W. Gould and K. W. Ray, and is published in "Metals and Alloys." The properties considered included specific gravity, tensile strength, impact strength, percentage of elongation, hardness, resistance to corrosion, and machineability.

In the experimental work involved three series of silicon brass samples were prepared, including one without silicon. The copper zinc ratios used were 85-15, 65-35, and 60-40. The percentage of silicon was progressively increased in each succeeding melt, and all samples were chill cast, the pouring temperatures being approximately 100° C. above the freezing point of the alloy.

As a result of these experiments the authors concluded that the specific gravity of a brass is uniformly decreased by increasing percentages of silicon. The hardness is rapidly increased by silicon until a maximum is practically reached at 9% silicon for the 85-15 brass, and at 7% silicon for 65-35 and 60-40 brasses. An 85-15 brass begins to become brittle at about 6% silicon, a 65-35 brass at 3% silicon, and a 60-40 brass at about 2% silicon.

The tensile strength increases to a maximum at about 4·5% silicon for 85-15 brass, and at about 1·5% silicon for 60-40 brass, while the impact breaking strength is greatest at about 3·3% silicon for 85-15 brass, at about 1·3% silicon for 65-35 brass and at less than 0·8% silicon for 60-40 brass. The percentage elongation for 85-15 brass is markedly increased by silicon to a maximum at about 1·5% silicon; the maximum for 60-40 brass is reached at about 1·0% silicon while the decrease in both tensile strength and percentage elongation is very rapid after the maximum value is exceeded.

Small percentages of silicon produce a very fine, compact structure in brasses, and improve the casting qualities; further, the ingots are clear and of a much better appearance than those without silicon.

Silicon has little effect in general on the corrosion resistance of 85-15 and 60-40 brasses, except when it is present in amounts sufficient to give an open, porous structure, in which case the rate of corrosion is increased.

Most of the silicon brasses are modified by heat treatment, and generally it can be assumed that silicon may be used in brasses where strength, hardness, and toughness are required, provided that lead and aluminium are absent.

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# PRIZE SCHEME OF INSTITUTE OF WELDING ENGINEERS.

The Council have decided to offer a prize of ten guineas, together with the Gold Medal of the Institution, for the best original paper submitted by a *bona fide* operative welder, whether gas or electric, on the subject of "Welding Practices and Methods, based on my own Experiences." The Institution will also present the prize winner with a permanent record of his success, and will arrange for the prize-winning paper to be read before a meeting of the members of the Institution.

# METALLURGIA

*The British Journal of Metals.*




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**Published Monthly by the Proprietors, THE KENNEDY PRESS LIMITED, at Kennedy House, Liverpool Road, Deansgate, Manchester.**

*Telegrams: "Kenpred," Manchester.* *Telephone: Central 0098.*

CONTENTS

METALLURGIA

THE BRITISH JOURNAL OF METALS.

# Rational Organisation.

THE rationalisation of our industries may or may not solve the unemployment problem, but the formation of vertical and horizontal amalgamations is a logical step in the evolution of industry, and this country cannot afford to lag behind America and Germany in organising her key industries so that she can compete successfully in the world's markets. The big coal and steel merger in Lancashire is one of the most significant developments of recent years, and it is the first instance of the Bank of England's new policy of assisting in the rationalisation of the heavy industries. It has been suggested that the Bank of England, through the Securities Management Trust, Ltd., is carrying out in advance the findings of Lord Sankey's Committee of Enquiry on the Iron and Steel Industries. It is, on the other hand, reasonable to express a doubt as to whether the Sankey Committee's findings will ever be made public, or indeed as to whether it would be advisable for them to be made public. The iron and steel industry of Great Britain depends to a certain extent on export trade, but also largely upon the home trade, and in both overseas and home markets foreign competition has become of increasing vital importance in recent years. There are those who believe that a modification of our fiscal system would give a fillip to the home trade, but it is only by the reduction of production costs that British manufacturers can hope to hold their own in foreign markets. A striking instance was referred to in the House of Commons of how an order was lost by a British engineering concern. A hundred and thirty-two boilers and sixty-six cylinders were required by an overseas buyer. The order was lost because the British firm's quotation was 20% too high. Commenting on this recently, Mr. A. M. Samuel, M.P., said that in effect, when similar orders are lost, what happens is this: The overseas buyer asks, " What is your price ? " When the price is quoted, he says: " I will give 20% less than that." We reply: " We cannot sell the goods at that price; our men could not live at the wages represented by that selling price." The buyer's rejoinder is: " I do not care twopence whether your men can live at that price; take it or leave it. If you leave it, I can, and will, buy the same goods elsewhere, and your men can go on the dole." It is beyond dispute that many overseas orders are lost in this way, and it is only by reducing production costs, either by lowering wages or by improving organisation and installing the most modern equipment that foreign competitors can be beaten on price.

It is a manifestly unjust charge, however, that the heavy industries of Great Britain are not efficiently equipped and organised. One of our chief statesmen said recently that the iron and steel concerns, during the prosperous period after the Armistice, paid out huge profits in dividends without making adequate reserve for the purchase of new plant. This unjust statement was confuted in a very convincing manner by one of the largest iron and steel concerns in this country. The announcement of a big merger in Lancashire is not to be taken as a confession by the amalgamating firms that they have not moved with the times. It is, on the other hand, a carefully considered scheme, by which the highest production efficiency can be maintained and costly overlapping eliminated. The companies included in the scheme are the Pearson and Knowles Coal and Iron Co., Ltd., the Moss Hall Coal Co., Ltd., the Wigan Junction Colliery Co., the Wigan Coal and Iron Co., Ltd., Partington Steel and Iron Co., Ltd., and Rylands Brothers, Ltd., Warrington, and a noteworthy point is that it is a horizontal amalgamation scheme, which is actually taking the place of vertical amalgamations. One of the two new companies will take over the colliery interests of the various concerns, while the other, called the Lancashire Steel Corporation, will take over the iron and steel assets of the amalgamating companies. It is announced that the share capital will be £5,750,000 and that arrangements have been concluded for the raising of fresh capital by means of an issue of 1,250,000 7% first preference shares of £1 at par, while the Securities Management Trust, Ltd., have subscribed for 500,000 " B " ordinary shares of the steel company. The fear has been expressed in some quarters that, as the first directors of the new steel corporation will be nominees of the Bank of England, financiers may be placed in charge of the company, but this is extremely unlikely.

The companies forming the new amalgamation have works that are laid out on modern lines, and there is every reason to believe that the merger will be for the good of the iron and steel industry of this country as a whole. It is noteworthy that it is proposed to construct a new dock with modern equipment on the Manchester Ship Canal, by-product coke-ovens of the most modern kind, blast-furnace and open-hearth furnace development, rolling mill additions, etc., at Irlam. With regard to the location of the various works, they are very favourably placed to work economically, not only by reason of their proximity to markets – because, after all, they must depend on national markets and on export trade—but also because of the excellent geographical situation of the works on the Manchester Ship Canal, with lines of railway alongside. This big merger may well be the forerunner of others in this country, and it is only by such means that the restoration of our heavy industries can be looked for. The tendency in this country is to give too great credit to our foreign competitors, and attribute to them commercial acumen and organising genius which they do not possess in a greater degree than ourselves. When every fact is taken into consideration, the iron and steel industries of Great Britain have been as progressive and enterprising as those of the United States and Germany, and the economic factors which have caused the long-continued depression here have not been within the control of the suffering industries.

*In our July Issue special consideration will be given to developments in foundry plant and equipment.*

## The International Congress at Liege.

THE organisation of the programme for the Sixth International Congress of Mining Metallurgy and Applied Geology, to be held at Liege from June 22 to 28, must have been a stupendous task, and the foresight which has been displayed reflects great credit upon the Committee responsible. The subjects that have been chosen in each section are very comprehensive and leave little to be desired. In the metallurgy section the subjects are eminently practical and will have a very wide appeal. For convenience the papers to be presented have been arranged in sub-sections ; thus the whole section is divided into six parts.

Consideration of the blast-furnace forms one of these ; attention being directed particularly to practice with blast-furnaces with rapid driving, in which, the raw materials, burdens, yields, and equipment are proposed for discussion. In addition, the by-products and their utilisation will receive consideration.

The manufacture of steel and ferrous alloys will be discussed under three main headings ; these include the problems of corrosion, and will cover a general study of the properties of steels subjected to varying stresses at high temperatures ; progress in the casting of steel ingots, and the influence of deoxidisers : a consideration of rails manufactured by different metallurgical processes ; new developments, and a comprehensive presentation of the rolling of sheets.

The papers in the foundry sub-section have been classified under four main subjects. A session being allocated to methods of testing cast iron, and among the papers to be presented are the Czecho-Slovakian and the British exchange papers. The problems associated with special cast irons and malleable cast iron have been allocated separate sessions, as also has the consideration of moulding sand, together with various miscellaneous subjects, including the American exchange paper.

The non-ferrous metals sub-section is not less comprehensive. Primary consideration will be given to the influence of the concentrations of ores by flotation on their metallurgical treatment and the electrolytic production of metals, and, in addition, repercussion on the Belgian metallurgical industry of mining and metallurgical developments in the Belgian Congo is proposed for discussion. A further sub-section is allocated to non-ferrous alloys, particularly referring to aluminium, magnesium, and beryllium alloys. It is also intended to discuss non-ferrous alloys for cutting tools as well as alloys containing cobalt. The importance of fuel in all metallurgical processes is fully recognised, and the papers to be presented in this sub-section refer to the reactivity of fuels ; the utilisation of gaseous fuel in various connections, and thermal control.

The International Exhibition of Industry and Science, which is in progress at Liege is organised on a large scale, and portrays the development of Belgian industry and art.

## Research in Non-Ferrous Metallurgy.

THE importance of intensive research work was emphasised at the annual meeting of the British Non-ferrous Research Association, held in Birmingham recently under the chairmanship of Mr. Thomas Bolton. The report indicated that the keenest competition comes from those countries where active scientific and industrial investigation is in progress. Within the last few years provision has been made in Germany and the United States for co-operative research, and expansion is taking place at a great rate. The question, therefore, needs emphasising if we are to maintain our competitive power so far as this is possible by the application of science to industry. The research results of the Association during the last year had exceeded in importance and volume any previous record, despite a curtailment of the programme. In addition, great strides have been made in development work.

The report further stated that they now possess nucleus of a really strong organisation, much more competent to-day to afford service than ever before. They realised that even investigations, which in the early days appeared too abstract, had in time promised a harvest of new knowledge which could be applied to immediate industrial objectives.

At the luncheon, held at the Grand Hotel, the President, Mr. Bolton, said they had reached an important stage in their history. Through the operation of the new terms of the Government grant, there was possible a very considerable expansion of their work, provided they were able to make a sufficient effort themselves, and he asked those who had the interest of the progress of this country at heart, and were directly concerned in the work of the Association, to assist in every possible way. British industry to-day, he added, is labouring under a great many burdens, and it is remarkable what we have been able to accomplish when the many difficulties are considered.

In dealing with the progress of industry, Dr. F. E. Smith, Secretary of the Department of Scientific and Industrial Research, said progress was due to discovery. Occasionally discovery was accidental, but the bulk was due to the intense pursuit of knowledge on the part of groups of people or an individual. With regard to industry—was it necessary for it to be convinced of the need of scientific research ? Mr. Smith's reply was " Yes." If they took industry in general they would find that those industries that were founded on a scientific basis and had worked hand in hand with science never suffered when there was a general depression in the country.

Speaking of the work of the organisation, Dr. H. W. Brownsdon, the Vice-Chairman of the Association, considered the future was rosy. They had gained a great deal of experience. What they had to do now was to put that experience into practice.

## British Foundrymen's Convention.

THE Convention of the Institute of British Foundrymen has been arranged to take place at the Constantine Technical College, Middlesbrough, from June 17 to 20. It is particularly appropriate that Middlesbrough should have been chosen, not only because the President-elect of the Institute, Mr. F. P. Wilson, is actively associated with the local section of the organisation, but because of the energy displayed in the district for improvement in foundry matters.

The Conference commences on June 18, when an official welcome will be extended by the Mayor of Middlesbrough, and, following the presentation of the Oliver Stubbs' Medal, the Annual General Meeting will be held. The papers to be presented cover a wide range of subjects appertaining to the work in the foundry, and an international character is given to the Conference by the presentation of exchange papers. These will be given on behalf of the American, French, and Belgian foundry associations. In addition to the presentation and discussion of papers a very full programme has been arranged, including visits to important works in the vicinity. Adequate arrangements have been made to provide an excellent social atmosphere for members and their friends, and a special programme is prepared for the ladies. There is every likelihood that this Convention will be as successful as any previously held, and we are quite sure the foundrymen of the Middlesbrough district will welcome and do their utmost to make the visit profitable to all who attend the various functions.

## *Forthcoming Meetings*

June 22—28. Sixth International Congress of Mining, Metallurgy, and applied Geology at Liege.

June 16—25. Second World-Power Conference, Berlin.

June 21—28. Summer meeting of the Institutions of Engineers and Shipbuilders of Scotland and the North-East Coast in Holland.

June 17—20. Convention of the Institute of British Foundrymen at Middlesbrough.

June 23—25. Summer meeting of the Institution of Heating and Lighting Engineers at Eastbourne.

# Hiduminium—A New Alloy Development

REMARKABLE progress has been made in the development of aluminium and its alloys during recent years, as a result of technical advances and departures from previously established practice. Developments have been effected which have decreased the cost of production, given new products, or so improved the material that it possesses superior mechanical or other properties. Special compositions have been developed which are adapted particularly to sand founding, die-casting, forging, rolling, extruding and other purposes. The success that has attended the efforts of various investigators is indicated by the constantly expanding market for aluminium alloy manufactures, and it is interesting to note how rapidly general knowledge regarding this metal and its alloys has become so widely diffused. Nevertheless, it seems that only the surface of its possibilities has been touched, and with investigations proceeding and the same rate of progress maintained, the uses of the light alloys in the future will show a corresponding expansion.

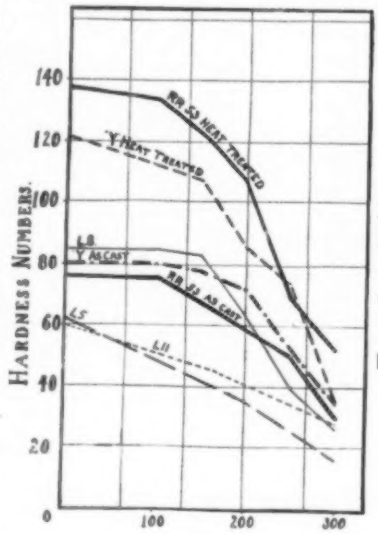


*Fig.* 1.

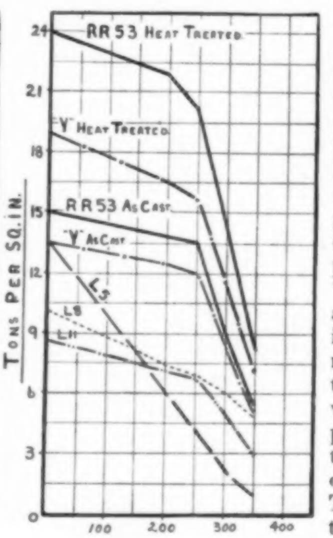


*Fig.* 2.

One of the most recent investigations in this field has been carried out at the laboratory of the Rolls-Royce Co. by Messrs. Hall and Bradbury. These investigations have resulted in the production of what is regarded as a new alloy, and for which Letters Patent have been issued. This alloy is known as "Hiduminium" R.R. 50, and, in the aircraft industry particularly, it is considered to represent a distinct advance in the development of aluminium. Its qualities are indicated by its use in the famous engine installed in the plane which won the Schneider Trophy, in which the crankcase, cylinder-block and cylinder head were produced from this new alloy. Much development work in regard to this material has been done by High Duty Alloys Ltd.

The composition consists of a variety of elements having the following approximate percentages :—

| Copper. | Nickel. | Magnesium. | Iron. |
|---|---|---|---|
| 0·5 to 5·0 .. | 0·2—1·5 .. | 0·1—5·0 .. | 0·6—1·5 |

| Titanium. | Silicon. | Aluminium. |
|---|---|---|
| to 0·5 .. | 0·2—5·0 .. | Remainder |

Investigations with compositions containing elements within these wide limits have resulted in the production of four grades—one for sand and die-castings for general purposes ; one for die-castings for pistons ; another for forgings for general purposes ; and a fourth for forgings for high quality pistons. All the grades used are strengthened as a result of suitable heat-treatment. The castings only require a comparatively low temperature for heat-treatment, not higher than 175° C., so that distortion or cracking on quenching are very much reduced or obviated entirely. The forgings on the other hand, have a high heat-treatment, and, after being quenched, are subjected to an ageing process.

Various grades of this new alloy have been used to a considerable extent in the construction of the Rolls-Royce engines in Sir Henry Segreave's new boat, "Miss England." Although originally designed to give 875 h.p., each unit was lightened and modified by a more extended use of this alloy until it delivered nearly 2,000 b.h.p., with a power-weight ratio of 12 oz. per brake-horse-power ; and this with an even greater factor of reliability than before.

It is claimed that Hiduminium is not only lighter and tougher than aluminium alloys formerly used, but has many times their resistance to fatigue under the stress of heat and prolonged vibration. Another feature of this new alloy is that it is cheaper to produce than former alloys, and is eminently a commercial proposition.

Tests have been made with these grades, in comparison with other known aluminium alloys, to show the relative effect of elevated temperatures on the Brinell hardness and tensile strength. A particular grade has been specially developed as a die-cast piston alloy, known as "Hiduminium" R.R. 53, and the tests gave some interesting results. The results of Brinell hardness tests on this alloy at varying elevated temperatures, as cast and in the heat-treated condition, are shown in Table I. These are plotted in comparison with the known Brinell hardness of other aluminium alloys, and shown in Fig. 1. It will be noted that only at a temperature of 250° C. is there any similarity with

TABLE I.

| Temperature of Test. | Hardness No. | | After Cooling Hardness No. | |
|---|---|---|---|---|
| | As Cast. | Heat-treated. | As Cast. | Heat-treated. |
| Normal | 76 | 138 | — | — |
| 100° C. | 76 | 134 | 76 | 138 |
| 150° C. | 72 | 121 | 85 | 138 |
| 200° C. | 69 | 107 | 85 | 138 |
| 250° C. | 50 | 68 | 80 | 121 |
| 300° C. | 30 | 52 | 65 | 104 |

heat-treated "Y" alloy, while at all other temperatures the hardness of heat-treated R.R. 53 is greater. The tensile strength of this alloy at various temperatures is shown in Table II. A comparison with the known tensile strength of other alloys at similar temperatures and with test pieces 1 in. dia. of chill cast bars is indicated in Fig. 2.

It is interesting to note that the casting of "Hiduminium" is claimed to be easier than any other known alloy—as easily as an aluminium-silicon alloy. It is notably free from hot-shortness and shrinkage cracks : and it gives a dense casting. The material is very fluid ; high temperatures, for casting thin sections, can be adopted with-

out detriment, and, if cast correctly, it is not necessary to use chills in sand moulds. The material is easily die-cast, and apparently, it is unnecessary to alter existing

TABLE II.

| Temperature of Test. | Tensile Strength, Ton per Sq. In. | |
|---|---|---|
| | As Cast. | Heat-treated. |
| Normal | 15·00 | 24·00 |
| 200° C. | 13·80 | 22·00 |
| 250° C. | 13·50 | 20·00 |
| 300° C. | 9·00 | 14·50 |
| 350° C. | 5·50 | 8·20 |

Test pieces in the form of 1¼ in. diameter chill-cast bar. Held at temperature for 1½ hours.

dies to receive this alloy. The machining calls for some extra care and is more difficult in this respect than an aluminium-silicon alloy. The cutting rakes of the tool need to be more than in the case of Y-alloy, corresponding more nearly to those used in machining mild steel.

## CHEMICAL COMPOSITION AND MECHANICAL PROPERTIES OF CENTRIFUGAL CASTINGS.

(*Continued from page 56.*)

cast material. This rapidly becomes less as the test proceeds, and finally reaches a constant value, the total value being nearly half that of the sand-cast material, which steadily decreases in resistance to wear as the test proceeds. It is appreciated that isolated tests are of doubtful value

CENTRIFUGALLY CAST METAL.

| | Weight. Grammes. | Loss in Weight. Grammes. |
|---|---|---|
| Original weight ......... | 6·7500 | — |
| After $3 \times 10^6$ revolutions | 6·7349 | 0·0151 |
| „ $4 \times 10^6$ „ | 6·7339 | 0·0010 |
| „ $5 \times 10^6$ „ | 6·7335 | 0·0004 |
| „ $7 \times 10^6$ „ | 6·7331 | 0·0004 |
| Total loss | | 0·0169 |

SAND CAST MATERIAL.

| | Weight. Grammes. | Loss in Weight. Grammes. |
|---|---|---|
| Original weight ......... | 6·7530 | — |
| After $3 \times 10^6$ revolutions | 6·7445 | 0·0075 |
| „ $4 \times 10^6$ „ | 6·7425 | 0·0030 |
| „ $5 \times 10^6$ „ | 6·7325 | 0·0100 |
| „ $7 \times 10^6$ „ | 6·7220 | 0·0105 |
| Total loss | | 0·0310 |

in the case of such a complex property as resistance to wear, and that this property is vitally affected by the conditions under which the wearing action takes place. The most important fact which has emerged from the many wear tests made by different observers on centrifugal castings is that unless the material has a minimum combined carbon content of 0·40% the rate of wear is likely to be very high. For this reason the minimum value given in the specification is adhered to very rigidly.

A new heat-resisting alloy produced by Messrs. Hadfields has been applied to the construction of an electric furnace, which has already been in use for a total period of 2,000 hours at a temperature of 1,200° C. without showing any signs of deterioration. Even at a temperature of 1,400°, which is approaching the melting point of most steels, wastage by scaling still goes on very slowly with this alloy.

## THE VERTICAL RING INDUCTION FURNACE.

THE specifications for an ideal electric furnace for melting non-ferrous metals were referred to in a paper presented at the general meeting of the American Electrochemical Society, by William Adam, Jnr. Operating data were given to support the claim that the vertical ring induction furnace more nearly meets these specifications than any other type of furnace. As this type of furnace is essentially a power transformer, it may be designed to use any commercial frequency and voltage, and many are in successful operation on 25, 30, 50 and 60 cycle units. They are supplied directly from the low-tension side of standard power transformers, the usual voltages being 220, 440, or 550 volts.

In the vertical ring induction furnace the electrical and thermal efficiencies are practically identical. During the melting cycle the line voltage is applied directly to the furnace transformer which causes a voltage to be induced in a part of the metal bath. This part of the bath constitutes a short-circuited secondary, and consequently, heat is generated directly in the metal itself, and the time required to melt does not depend upon the thermal resistance of a refractory wall or the metal surface. Some indication of the high melting efficiences which are being obtained in actual commercial melting practice with non-ferrous metals and alloys is shown in Table I.

TABLE I.

75-Kilowatt Ajax-Wyatt Electric Furnace.

| Metal. | Nature of Charge. | Product. | Kw.-hr./ton to Melt Including Superheat. | Kw. Required to Hold Overnight. | Net Metal Loss. |
|---|---|---|---|---|---|
| Red brass : 85-5-5-5 | Heavy scrap.... | Valves .. | 252 | 11 | 0·4% |
| 2 : 1 Yellow brass | Heavy scrap and new metals. | Extrusion billets. | 195 | 8 | 0·3–0·6% |
| Alloy : 75% Cu ; 2% Sn ; 3% Pb ; 20% Zn. | Scrap and ingots | Plumbing fittings. | 205 | 8 | 0·5% zinc |
| Nickel-silver ..... | New metals and sheet scrap (50-50). | Sheet ... | 290 | 12 | 0·6% zinc |
| Steam metal : 87% Cu ; 6% Sn ; 5% Zn ; 2% Pb. | Ingot, gates, sprues, etc. | Valves .. | 260 | 12 | 0·5% zinc |
| Bronze : 95½% Cu ; 4½% Sn. | 50% new metals, 50% scrap. | Sheet and rods | 285 | 12 | 0·7% gross |
| Pure copper ..... | Selected scrap and ingot. | Extrusion billets. | 310 | 13 | — |
| Zinc ............ | Slabs ......... | Sheet ... | 90 | 4½ | 0·25% dross |

It is claimed that there are few large power consuming devices that have as smooth an operating curve as this type of furnace. Perhaps its most unique feature is the manner in which it produces an automatic stirring action, to ensure a homogeneous alloy and keep the metal losses to a minimum, but this circulation also tends to purify the metal by causing oxides, dross and dirt to rise to the top of the bath. Then, as the source of heat is in the metal itself, the induction furnace does not generate gases or any other product of combustion likely to contaminate the metal.

In many furnaces the source of heat provides a temperature much higher than the more common non-ferrous alloys. Obviously, such a heat source cannot be applied directly to brass or bronze alloy, and, in consequence, it must be conveyed to the metal either by radiation, convection and conduction, or a combination of these. The induction furnace of the type referred to is an exception, as the metal bath is the hottest part of the unit, and there is an instant response in temperature when the power is thrown on or off. The heat being generated at the bottom of the furnace also facilitates the removal of dirt and dross without the operator being met with a blinding incandescence.

The power input of the vertical ring induction furnaces varies from 45 to 150 kw., and the pouring capacity from 400 to 2,200 lb. per heat. Single phase is considered to be preferable on account of its extreme simplicity.

# Chemical Composition and Mechanical Properties of Centrifugal Castings.*

By J. E. Hurst.

FOR convenience in the industrial testing of centrifugal cast pipes a form of test has been devised utilising an annular ring test-piece. This form of test-piece can be turned readily off the end of the cast pipe, thus avoiding the difficulty of cutting out longitudinal strips, and at the same time providing a test of the actual material as centrifugally cast. A ring cut from a pipe is pulled apart under a diametral load applied as shown in the sketch, Fig. 9. The formula devised for calculating the tensile strength from this test is as follows :—

$$f = \frac{P\,(D - t)}{4{,}000\; b\, t^2}$$

Where P = breaking load in pounds; D = mean diameter in inches; $b$ = breadth of ring in inches; $t$ = thickness of ring in inches.

This test is embodied in the British specification for centrifugal cast pipe, where it is required that a ring not exceeding 1 in. wide shall be cut from the pipe and shall show a breaking stress of not less than 15 tons per square inch when calculated by the above formula. The results obtained in practice vary from 17 to 20 tons per square inch, whilst the results from sand-cast pipes are usually of the order of 10 to 12 tons per square inch. Whilst referring to specification, it is of interest to note that the specification accepted by the United States Cast Iron Pipe Co. for centrifugal cast pipe requires a tensile test-piece to be cut from the spigot end of the pipe, and that this shall sustain a tensile stress of not less than 30,000 lb. per square inch.

*Impact Tests.*—A series of impact tests on centrifugal cast pipe has been recorded by Menefee and White. These tests were carried out on the Izod, Olsen, and Baby Olsen machines, of the single-blow type. The average results obtained on a variety of test-pieces, tested in different manners, are given in the following tables. In a number of cases the impact resistance of the sand-cast material is better than that of the centrifugal material. It is important to remember that these tests were made on pipes drawn from commercial stocks, and there is no detailed information of their previous history. The centrifugal cast pipes tested were made by the Lavaud process, in which the pipes are required to be annealed. The impact resistance value will be affected obviously by the correctness or otherwise of the annealing treatment. The above observers made reference to this, and carried out a series of tests designed to demonstrate the influence of annealing on the impact resistance value. The average value obtained on unannealed pipes was approximately 9 ft.-lb., whilst on the annealed pipes a value of 18 ft.-lb., approximately twice that of the unannealed pipes, was obtained.

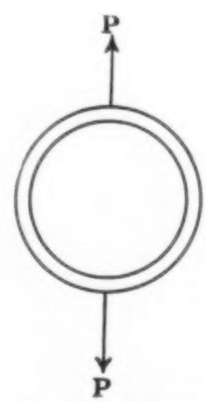

*Figure 9. Method of Loading Ring.*

* *Continued from page 16 in May issue.*

IMPACT VALUES.

| Test. | Size of Pipe. | Impact Resistance. | | Size of Test Piece. | Remarks. |
|---|---|---|---|---|---|
| | | Sand Cast. | Cent. Cast. | | |
| | In. | Ft.-lb. | Ft.-lb. | In. | |
| Izod | 6 | 1·345 | 1·716 | 0·315 × 0·409 | No notch. Blow on O.D. of pipe. |
| ,, | 6 | 1·27 | 1·465 | 0·315 × 0·409 | |
| Olsen | 6 | 0·53 | 0·877 | 0·315 × 0·409 | |
| Standard | 8 | 0·423 | 0·959 | 0·315 × 0·409 | |
| ,, | 6 | 0·459 | 0·28 | 0·315 × 0·409 | Notched. Blow on O.D. of pipe. |
| ,, | 6 | 0·368 | 0·28 | 0·315 × 0·409 | |
| ,, | 6 | 0·42 | 0·318 | 0·315 × 0·409 | |
| ,, | 8 | 0·455 | 0·29 | 0·315 × 0·409 | |
| Baby | 6 | 8·63 | 4·05 | 0·105 × 0·409 | No notch. Blow on O.D. of pipe. |
| Olsen | 8 | 13·63 | 12·22 | 0·105 × 0·409 | |
| ,, | 6 | 18·63 | 8·75 | 0·105 × 0·409 | Notched. Blow on I.D. of pipe. |
| ,, | 8 | 23·30 | 11·68 | 0·105 × 0·409 | |
| ,, | 6 | 17·55 | 10·30 | 0·105 × 0·409 | Notched. Blow on O.D. of pipe. |
| ,, | 8 | 18·65 | 11·7 | 0·105 × 0·409 | |

*Brinell Hardness.*—The Brinell hardness determinations of sand-cast and centrifugal-cast pipe, tested during the experiments of Menefee and White, are given below :—

| Mark. | Size of Pipe. | Brinell Hardness. | |
|---|---|---|---|
| | | Sand Cast. | Centrifugal Cast. |
| — | 6 | 187 | 215 |
| — | 8 | 192 | 241 |
| O3 | 6 | 163 | 187 |
| N3 | 6 | 153 | 191 |
| O3 | 8 | 187 | 205 |
| N3 | 8 | 187 | 196 |
| | Average | 178 | 206 |

The average results obtained in these American experiments are higher than that of English made pipes by the Lavaud process. The average of approximately 2,000 tests of the latter is given by Fox and Wilson as 182.

*Sand-spun Pipe.*—The above mechanical test considerations have been concerned with centrifugal cast pipe made in metal moulds. A series of comparative tests of pipes made in sand moulds by the sand-spun process is abstracted from the tests of Talbot and Richart[1] in Table II. The results in column (1) of the table show the tensile strength in tons per square inch, calculated from the hydraulic internal bursting pressure. The mean results on this show that pipe centrifugally cast has 38% greater strength than ordinary sand-cast pipe. The results given in column (2) are derived from the sum of the differences between each test and the average (regardless of sign) and divided by the total number of tests. The centrifugal cast shows only a little more than half the deviation of the ordinary sand cast, this indicating greater uniformity, in addition to greater strength. The impacts in column (3) are calculated to show the height of drop necessary to break the pipe if it were exactly 1 in. thick. These results are designed to show the relative ability of the two products to withstand external blows. The remaining columns give the results of flexure tests, both on pipe and test strips cut from pipe. The results show a 25% greater

[1] American Iron and Steel Institute, October, 1927.

modulus of rupture and 10% greater modulus of elasticity for the centrifugal cast material. The "full resilience factor" is obtained by dividing the square of the modulus of rupture by the modulus of elasticity, and correcting for any curvature in the specimen. This figure represents the relative amount of work done in breaking the specimen or the capacity of the specimen for storing energy. These casting conditions are controlled in such a manner that the castings are produced grey and machinable without the necessity of any annealing operation. The characteristic fine structure of such castings was illustrated in the microphotographs given in the previous article.

*Tensile Strength.*—The method of determining the tensile strength of piston ring castings differs somewhat from the special method devised for centrifugal cast pipes. In this test a ring form of test-piece cut from the casting is used. The ring is of the form of a piston ring, complete with gap, and in testing it is pulled apart by a load applied at opposite ends of a diameter at right-angles to that through the joint. The type of machine used for this purpose is illustrated in Fig. 10. The load applied in this manner imparts a transverse stress to the ring, and from the breaking load the transverse breaking stress can be obtained in the following manner :—

TABLE 2.

SUMMARY OF RESULTS OF TESTS ON CAST-IRON AND SAND-SPUN PIPE.

| | Internal Pressure Tests. | | Impact Tests. | Flexure Tests on Pipe. | | | Flexure Tests on Strips. | |
|---|---|---|---|---|---|---|---|---|
| Test No. | Bursting Strength. Lb. per Sq. In. | Mean Deviation % of Average Strength for Each Lot. | Height of Drop Divided by Square of Average Thickness in Inches. | Modulus of Rupture. Lb. per Sq. In. | Mean Deviation % of Average Strength for Each Lot. | Secant Modulus of Elasticity. Lb. per Sq. In. | Modulus of Rupture. Lb. per Sq. In. | Secant Modulus of Elasticity. Lb. per Sq. In. |
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| | | | Group 1. | Vertically Cast Sand Mould. | | | | |
| 1 | 13,900 | 4·8 | 16·7 | 29,000 | 3·8 | 10,150,000 | 35,300 | 7,500,000 |
| 4 | 16,100 | 10·3 | 16·6 | 32,200 | 6·4 | 9,400,000 | 38,300 | 7,200,000 |
| 20 | 14,700 | 9·2 | 14·0 | 27,000 | 2·2 | 10,030,000 | 33,900 | 7,710,000 |
| 30 | 13,700 | 2·6 | 15·3 | 26,800 | 0·7 | 9,130,000 | 33,700 | 6,630,000 |
| 40 | 13,400 | 15·6 | 20·3 | 29,300 | 7·1 | 10,200,000 | 39,100 | 7,430,000 |
| 70 | 14,800 | 3·9 | 14·4 | 28,400 | 5·3 | 10,070,000 | 35,000 | 7,160,000 |
| 71 | 14,600 | 9·3 | 16·0 | 26,300 | 2·7 | 9,600,000 | 29,300 | 6,870,000 |
| 72 | 14,400 | 3·7 | 18·2 | 26,900 | 6·5 | 9,030,000 | 32,300 | 6,610,000 |
| 73 | 16,400 | 7·3 | 14·2 | 26,800 | 4·9 | 10,940,000 | 35,500 | 7,320,000 |
| Average | 14,700 | 7·4 | 16·2 | 28,100 | 4·4 | 9,840,000 | 34,700 | 7,160,000 |
| Full resilience factor .... | | | | | 95 | — | 207 | — |
| | | | Group 2. | Centrifugal Process. Sand Mould. | | | | |
| A | 20,200 | 1·9 | 16·4 | 39,500 | 2·4 | 9,750,000 | 43,500 | 7,530,000 |
| B | 20,800 | 6·5 | 19·0 | 30,700 | 3·5 | 10,520,000 | 41,100 | 7,950,000 |
| F | 19,600 | 3·5 | 16·1 | 37,500 | 4·4 | 10,420,000 | 43,000 | 8,250,000 |
| 75 | 20,600 | 5·7 | 18·1 | 38,600 | 8·5 | 9,920,000 | 46,000 | 7,670,000 |
| Average | 20,300 | 4·4 | 17·4 | 36,600 | 4·7 | 10,150,000 | 43,400 | 7,850,000 |
| Full resilience factor .... | | | | | 158 | — | — | 316 |

figures show that the centrifugal cast material has 66% greater resilience in the pipe tests and 53% greater in the tests made on test strips.

Mackenzie[2] gives the following average results of sand-spun cast pipes :—

| | |
|---|---|
| Modulus of rupture ....... | 46,000 lb. per sq. in. |
| Modulus of elasticity ...... | $7 \cdot 89 \times 10^6$ lb. per sq. in. |
| Brinell hardness .......... | 200. |
| Tensile strength .......... | 29·600 lb. per sq. in. |
| Resilience factor .......... | 357. |

*Centrifugally Cast Material for Piston Rings and Cylinders.*—A different standard of mechanical properties is required in material for piston rings and cylinders than for cast-iron pipe. For example, the principal requirements of piston rings are : (*a*) That they shall exert a uniform pressure at all points round the circumference of the cylinder wall ; (*b*) that this uniform pressure shall be maintained throughout the life of the rings ; (*c*) that they shall be sufficiently strong to withstand the stresses to which they are subjected in handling and fitting over the piston ; (*d*) that they shall withstand the wearing conditions of rubbing under pressure against the cylinder walls. To meet these requirements in a given design of piston ring, the material is required to have a sufficiently high modulus of elasticity, strength, freedom from permanent set, and resistance to wear. The centrifugal process has enabled the high standard set by modern requirements for these properties to be obtained. The centrifugal casting methods adopted for the production of such special castings utilise metal moulds, and the

[2] American Water Works Assoc., 1926.

Where S = tensile strength in tons per square inch ; P = breaking load in pounds ; D = diameter of free ring in inches ; $b$ = breadth of ring in inches ; $t$ = thickness of ring in inches.

$$S = \frac{P\,D}{1200\,b\,t^2}$$

This formula is used in testing the tensile strength of piston ring material in accordance with the requirements of B.E.S.A. specification for aircraft material 4 K 6. The factor 1200 involves a constant which has been obtained by testing a large number of rings against test-bars from the same material. This specification requires that the ring shall sustain a stress without breaking equivalent to a tensile strength of 16 tons per square inch when calculated by the above formula. It is admitted that the use of a constant in the above formula is an objectionable feature, as it can only apply strictly to the conditions under which the constant was determined. This objection is overcome largely by the use of the transverse breaking stress figure

or modulus of rupture. The transverse modulus of rupture corresponding to the limit of 16 tons per square inch tensile strength calculated from the above formula is 25.6 tons per square inch. The tensile strengths obtained in practice, utilising the above formula and method of testing, vary between 18 to 25 tons per square inch, according to the composition of the material.

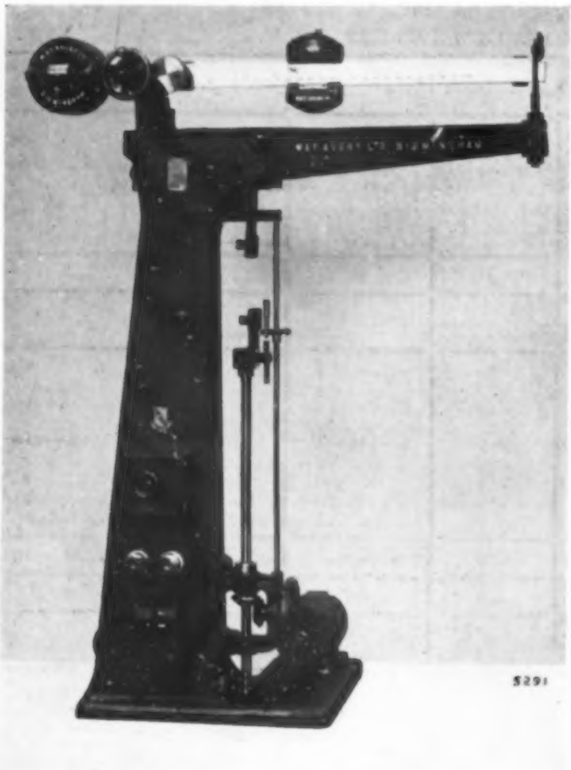

*Fig. 10. Type of Machine used for Ring Testing.*

A series of direct tensile tests made on small test-bars machined from the radial thickness of the castings are given in the following table. The ring tests from the same castings are also included for comparison :—

| Test No. | Gauge Length. | Diameter. | Area Square. | Breaking Load. | Ultimate Str'ngth. | Calculated from Ring Test. |
|---|---|---|---|---|---|---|
| | In. | In. | In. | Tons. | Tons per Sq. In. | Tons per Sq. In. |
| 19209 | 1·0 | 0·247 | 0·0479 | 0·88 | 18·38 | 20·2 |
| 19205 | 1·0 | 0·249 | 0·0487 | 0·85 | 17·46 | 19·8 |
| 19203 | 1·0 | 0·249 | 0·0487 | 0·78 | 16·03 | 19·7 |

*Permanent Set.*—An arbitrary form of test has been designed for the comparative determination of the permanent set of material for piston ring purposes. The ring test-piece as used in Specification 4 K 6, already mentioned, is used for the test. The ring is stressed to a load equal to 14 tons per square inch, calculated from the formula above, and the increase in the diameter through the line of loading is obtained. The load is released, and the permanent increase in diameter is measured. This value, expressed as a percentage of the increase in diameter under load, is the permanent set value. Centrifugal cast material has a value of not more than 15% when calculated in this manner, which compares favourably with sand-cast material of 18 to 20%.

*Elasticity.*—The determination of the elasticity on piston ring material is performed on a gapped ring of the type used in the tensile test described above. The test ring is machined from the casting in accordance with the following instructions : The thickness of the test ring shall not be less than the diameter of the ring before cutting the gap divided by 34, and a piece shall be cut out of the ring so as to leave a free gap of not less than $2 \cdot 75\ t$ and not more than $3\ t$. The width of the ring ($b$) and the radial thickness ($t$) shall then be determined, and a diametral load ($Q_1$) lb. sufficient to close the gap to less than $0 \cdot 25\ t$ shall be applied. The change in gap ($\delta_1$) and the mean external diameter of the closed ring ($d$) shall be measured. The elasticity or $E_N$ value can then be calculated from the following relationship :—

$$E_N = \frac{5 \cdot 37 \left(\frac{d}{t} - 1\right)^3 Q_1}{b\, \delta_1}$$

It is recommended that the mean external diameter of the ring in the closed position shall be calculated from the measurement of its circumference taken by means of a calibrated tape, and in order to remove a degree of permanent set from the ring the change of gap shall be measured on a second test—viz., after the ring has been closed, once allowed to open, and again closed. Special apparatus has been designed for the performance of this test under conditions of diametral loading of the form illustrated in Fig. 11.

The symbol $E_N$, used to indicate the modulus of elasticity determined in this manner, indicates the nominal modulus of elasticity, and recognises the fact that cast iron is not truly elastic. The values obtained in the above manner are only comparative amongst themselves, and vary somewhat from the values derived from careful extensometer measurements performed on direct tensile bars. The specification calls for a minimum $E_N$ value of $15\frac{1}{2}$ million pounds per square inch.

Whilst cast iron is not truly elastic, experiment shows that it more nearly approaches to true elastic behaviour when the $E_N$ value is high. Centrifugal cast material generally has a higher value of elasticity than sand-cast material, and is consequently more truly elastic. Hence the value of centrifugal cast material for piston ring manufacture.

*Hardness and Resistance to Wear.*—The Brinell hardness value of centrifugal cast material in the form of piston ring drums for automobile rings and to the composition requirements of the specification varies from 200 to 230. The determination of the resistance to wear is a matter of great difficulty, owing to the very complicated nature of this property. One of a series of comparative tests made by the writer gave the following results. The tests were performed by rotating a weighed specimen against a rotating disc of cast iron under conditions of constant loading, without any lubrication. After a given number of revolutions the loss in weight undergone by the specimen was determined.

*Fig. 11. Special Apparatus Designed for Diametral Loading.*

These results are of interest in the fact that they show that during the early stages of the test the wear of the centrifugal cast material was greater than that of the sand-

(*Continued on page* 53.)

# Aluminium Bronze—A Corrosion-Resistant Alloy

By

Dr. Robert J. Anderson.*

ALTHOUGH known prior to 1860, and the subject of many investigations between 1880 and 1900, aluminium bronze has come to the forefront as an engineering material of construction only within the past 15 years. Commercial development has been very rapid in the last five years. Before the advent of the Cowles reduction process in 1885, aluminium bronzes were too costly for industrial applications, the selling price being dependent upon the cost of aluminium. This

*Fig. 1. Pickling basket made in aluminium bronze.*

metal was selling at \$12·00 per pound in 1886. The Cowles process entailed the direct reduction of alumina by carbon smelting in the presence of another metal—*e.g.*, copper. Intermediate copper-aluminium alloys were made which served as a basis for the production of aluminium-bronze compositions by the addition of copper. By this process the Cowles company was able to produce aluminium bronze to sell for as low as \$1·50 per pound of contained aluminium. With the development of the Hall-Héroult process for the reduction of aluminium the price of this metal dropped to \$1·00 per pound in 1892, and was lowered rapidly in the years immediately following. The Cowles process ceased to be economical and production was stopped. Since then aluminium bronzes have been made by the direct alloying of copper and aluminium.

The term " aluminium bronze " is a misnomer, since the word " bronze " in accepted alloy nomenclature is used to connote copper-tin alloys rich in copper. However, it is not a particularly objectionable term, and having now been so long in general usage will doubtless not be changed. By aluminium bronze is usually meant an alloy containing from, say, 2 to 16% aluminium, and the remainder copper (plus small to appreciable percentages of other metals—*e.g.*, iron, manganese, or nickel). The bulk of the commercial aluminium bronzes contain 5 to 11% aluminium. Diverse compositions, either in the simple binary or more complex alloys, combine remarkably good mechanical properties with excellent resistance to corrosion by many media. Although favoured in the early days because of their high strength, the aluminium bronzes have attracted interest in more recent years because of their resistance to corrosion, especially to attack by sulphuric acid. That aluminium bronzes were resistant to corrosion by sundry media was known prior to 1900, but various applications were out of the question, either because of the cost or of difficulty in manufacture. Troubles in the production of castings restricted the application of aluminium bronze for many years. At the present time the casting and working of aluminium bronzes are being handled in regular commercial production. Certain compositions of aluminium bronze are susceptible to heat-treatment—*i.e.*, the mechanical properties may be substantially enhanced by heating to suitable temperatures followed by quenching or by quenching and drawing.

Methods of casting and working, heat-treatment, resistance to corrosion, mechanical properties, metallography, and applications, as applied to the aluminium bronzes, have been treated at length in many published papers, and a large literature has been built up on the whole subject. In the present article aluminium bronzes are discussed mainly from the point of view of their corrosion resistance when in contact with various media, and their commercial applications under conditions requiring resistance to corrosive influences. A short bibliography on aluminium bronze is appended, the citations referring to papers dealing chiefly with the behaviour when exposed to corrosive media and with applications. Some few other references are given which tie in with the whole literaure so that those interested in other phases of the subject may pursue the matter further.

### Compositions and Mechanical Properties.

While many compositions have been used in practice for both aluminium-bronze castings and wrought products,

*Fig. 2. Acid tank fitted with aluminium-bronze trimmings.*

there has been some tendency toward standardisation in recent years. Patented compositions are very numerous. Most manufacturers of aluminium-bronze products—and there are relatively few companies which specialise in these

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alloys—have their own preferred compositions. Users of aluminium-bronze parts can probably do no better than to be guided by the advice of responsible manufacturers who have had extended experience with production and applications. The specific composition recommended depends in part on the service properties required, the corrosive medium, heat-treatment, if any, and whether the material is to be cast or wrought.

If the binary copper-aluminium alloys are to be called aluminium bronzes, then when iron is added the alloy may be called iron-aluminium bronze, and if manganese and nickel are present, the alloy may be referred to as

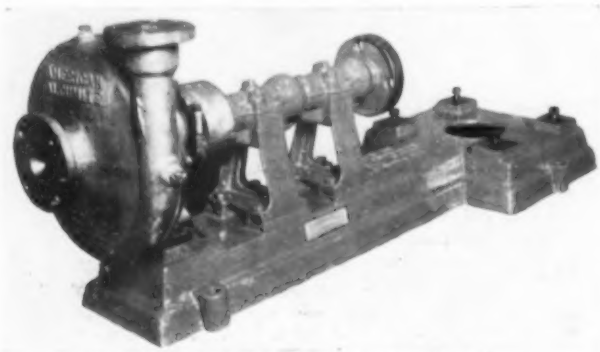

*Fig. 3. Centrifugal pump made of aluminium bronze.*

manganese-nickel-aluminium bronze. Most aluminium bronzes used for the production of sand castings, or permanent-mould castings, have been derived from modification in the composition of the 90 : 10 copper-aluminium alloy. This alloy is still used for castings, but most aluminium bronzes employed to-day are more complex. Alloys of copper and aluminium containing less than about 7·5% aluminium consist of a solid solution, are not heat-treatable, and are not subject to "self-annealing." The composition of the 90 : 10 copper-aluminium alloy is altered by the addition of other elements to (1) prevent self-annealing, (2) enhance the mechanical properties, (3) improve the resistance to certain corrosive media, (4) improve the casting or working qualities, and (5) increase the susceptibility to heat-treatment. Solid-solution binary copper-aluminium alloys, containing 5 to 8% aluminium, are used for some wrought products but seldom for castings; these alloys may contain small percentages of iron, manganese, or nickel.

The development of iron-bearing aluminium bronzes was the result of work by the American metallurgist, Vickers. In a patent[1] he specified alloys containing 7 to 12% aluminium, 3 to 5% iron, and remainder copper. Typical aluminium bronzes used for casting to-day in the United States include the following :—89 : 10 : 1, 87 : 10 : 3, and 88 : 9 : 3 copper-aluminium-iron. Two compositions of iron-aluminium bronzes are covered by tentative specifications of the American Society for testing materials, including a grade called A not responding to heat-treatment, and a grade B capable of heat-treatment. The requirements as to chemical composition are given as follows :—

| Grade A. % | Element. | Grade B. % |
|---|---|---|
| 87 to 89 | Copper | 89·5 to 90·5 |
| 7 to 9 | Aluminium | 9·5 to 10·5 |
| 2·5 to 4 | Iron | 1·0 (maximum) |
| 0·5 | Tin (maximum) | 0·2 |
| 1·0 | Total other impurities (maximum) | 0·5 |

1 C. Vickers, Alloy, U.S. Patent No. 1,264,459, April 30, 1918.

2 P. D. Schenck, Corrosion-resisting Alloy, U.S. Patent No. 1,651,970, December 6, 1927.

3 Metallbank and Metallurgische Gesellschaft A.-G., British Patent No. 268,654, April 15, 1926.

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Specifications have also been issued by United States Government departments. In a patent[2] the composition 89 : 7 : 3 : 1 copper-aluminium-iron-nickel is specified. In another patent[3] a complex copper-rich alloy is specified, the composition 84 : 9 : 1·5 : 5 : 0·5 copper-aluminium-iron-manganese-tin being mentioned. The composition 87·5 : 9·3 : 1·5 : 1·7 copper-aluminium-iron-silicon was sold by Cowles, as well as other alloys containing various percentages of silicon. The addition of silicon to aluminium bronzes is not regarded with favour to-day. In various patents, additions of lead, phosphorus, tin, magnesium, bismuth, silicon, chromium, zinc, and other elements are specifically mentioned.

Referring to the effect of the composition of aluminium bronzes on their resistance to corrosion : it may be said that while a given composition may be more resistant than another to attack by a specific corrosive agent, it does not inevitably follow that the first composition is necessarily better than the second as regards some other or any other corrosive. Thus, the binary alloys containing 10 to 12% aluminium and the remainder copper have been found to be more resistant to attack by dilute sulphurous acid than more complex compositions ; also, the addition of iron to the 90 : 10 copper-aluminium alloy increases its resistance to attack by dilute sulphuric acid. The presence of iron also improves the corrosion resistance of the binary alloy to some other acids, and the addition of nickel increases the resistance to corrosion by sea water. Some polynary compositions resist attack by specific media better than binary or ternary alloys. However, in any case, the differences in resistance to corrosion of the various aluminium bronzes are not great, and the usual commercial compositions recommended by manufacturers are highly resistant to attack by many agents that are corrosive to other engineering materials.

While the mechanical properties of the aluminium bronzes cannot be dealt with in detail here a few figures may be given to indicate the values obtained. The 90 : 10 copper-aluminium alloy as sand-cast has the following properties :—Tensile strength 72,000 lb. per sq. in., yield point 25,000 lb., elongation in a 2-in. length 22%, and Brinell hardness 95. When sand-cast and heat-treated the properties of this alloy are :—Tensile strength 90,000 lb., yield point 48,000 lb., elongation 8%, and Brinell hardness 175. The 89:10:1 copper-aluminium iron alloy, as sand-cast, has the following properties:—Tensile strength 74,000 lb., yield point 27,000 lb., elongation 24%, and Brinell hardness 95. The 88 : 9 : 3 copper-aluminium-iron alloy, as sand-cast, has the following properties : —Tensile strength 77,000 lb., yield point 31,000 lb., elongation 44%, and Brinell hardness 110. Worked aluminium bronzes are produced with tensile strengths in excess of 100,000 lb. per sq. in., and elongation of around 10%. The aluminium bronzes have excellent resistance to alternating fatigue and

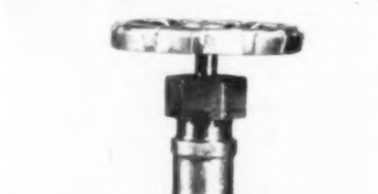

*Fig. 4. Gate valve of aluminium bronze.*

high compressive strength. Alloys of suitable compositions may be heat-treated to yield a considerable range of mechanical properties—*e.g.*, very high strength with low elongation or fairly high strength with high elongation, or some combination between the two. Heat-treatment may consist either of quenching from suitable temperature, or of quenching followed by drawing (reheating at a temperature considerably lower than the quenching temperature). The properties obtained depend upon the temperature of quenching and the time and temperature of drawing. For the 90 : 10 copper-aluminium alloy or some usual modification thereof, typical treatment consists in soaking at 900° C., followed by quenching, and then drawing at 400° to 700° C.—the drawing temperature selected depending upon the properties desired. Many detailed data regarding the mechanical properties of various compositions, as cast, wrought, and heat-treated, have been given in published papers (*vide* selected bibliography appended).

**Resistance to Corrosion by Various Media.**

The behaviour of aluminium bronzes when in contact with various corrosive agents has been studied by many investigators, including Carpenter and Edwards, Rosenhain and Lantsberry, Kowalke, Read, and Greaves, Schenck, and Corse. Roughly, aluminium bronzes are highly

TABLE 1.

LIST OF CORROSIVE AGENTS THAT ALUMINIUM BRONZE RESISTS AT THE ORDINARY TEMPERATURE.

| | | |
|---|---|---|
| Acetic acid | Embalming fluids | Sea water |
| Aluminium chloride | Ferrous chloride | Sodium bisulphate |
| Aluminium sulphate | Ferrous sulphate | Sodium carbonate |
| Ammonia liquors | Formic acid | Sodium chloride |
| Ammonium chloride | Hydrochloric acid* | Sodium hydroxide |
| Ammonium phosphate | Hydrofluoric acid | Sodium sulphite |
| Ammonium sulphate | Hydrofluosilicic acid | Stearic acid |
| Ammonium sulphide | Hydrogen sulphide | Sulphur dioxide |
| Atmosphere | Nickel sulphate | Sulphuric acid† |
| Barium chloride | Oleic acid | Sulphurous acid |
| Boric acid* | Oxalic acid | Tannic acid |
| Calcium hypochlorite | Photo developers | Titanic acid |
| Caproic acid | Oleum | Zinc chloride |
| Carbon tetrachloride | Lead acetate | Zinc cyanide |
| Cyanides | Maleic acid | Zinc sulphate |
| Citrus fruit juices | Malic acid | |

*With cold or weak hot solutions.

†60° Bé. and under at 80° C.; 45° Bé. and under at 132° C.

*Fig. 5. Sirocco type fan in aluminium bronze.*

resistant to attack by many of the ordinary corrosive influences met with in industrial operations, including ordinary air and polluted atmospheres, sea water, fresh waters, solutions of sulphuric acid over a rather wide range of concentration, alkaline liquors, certain concentrations of hydrochloric acid, a large number of neutral and acid salt solutions, many acids, and sundry gases. These alloys are, however, attacked by nitric acid, certain chloride and sulphate solutions, some contaminated waters, and some other acids and salts.

In a technical bulletin of the Aluminium-bronze Manufacturers' Institute, Washington, D.C., it is stated that aluminium bronzes of the usual commercial compositions

TABLE 2.

LIST OF CORROSIVE AGENTS THAT ATTACK ALUMINIUM BRONZE.

| | | |
|---|---|---|
| Calcium sulphide | Fluorine | Phosphoric acid |
| Chlorhydrin | Hydrochloric acid* | Sodium hypochlorite |
| Chromic acid | Hydrobromic acid | Sodium sulphide |
| Copper sulphate | Mercury or mercuric salts | Stannic chloride |
| Ferric chloride | Mine water | Stannous chloride |
| Ferric sulphate | Nitric acid | Sulphuric acid‡ |

*Concentrated hot.

‡Above 45° Bé. at 132° C.; above 60° Bé. at 80° C.

*Fig. 6. Filter press frame in aluminium bronze.*

are extremely resistant to attack at room temperatures by the list of corrosive media given in Table 1. In the case of salts, reference is made to solutions of any concentration; this also applies to acids unless otherwise stated. This list was compiled from available laboratory and service records, but is not to be regarded as complete. While the alloys are resistant to attack by all the agents listed at room temperature, they are also resistant in many cases to hot or boiling solutions. Aluminium bronzes are not recommended as suitable to resist attack by the corrosive agents given in Table 2, also from the bulletin of the above-mentioned Institute. Table 3 gives the results of some corrosion tests made on so-called Alcumite, a commercial aluminium bronze produced by The Alcumite Corporation, Dayton, Ohio.

Aluminium bronze is not to be regarded as a stainless or non-tarnishing alloy, since under the action of some corrosive agents greenish-brown films are quickly formed on the surface. However, in many, cases even although the alloy is stained the corrosive attack apparently goes no further, and there is no deterioration of the mechanical properties. Aluminium bronze stands up well in the highly destructive salt-spray test. Other than the agents listed in Table 1 aluminium bronzes resist corrosive attack by superheated steam, acid dyes, and many gases arising in industrial work (except gases from nitric acid), including chlorine, oxygen, hydrogen, and sulphur dioxide. At room temperature aluminium bronze is but slightly affected by hydrochloric acid in concentrations as high as 20%, while

TABLE 3.

CORROSION TESTS OF ALCUMITE AT 80° C.

| Corroding Medium. | Concentration, % | Loss in inch per Year |
|---|---|---|
| Acetic acid | Concentrated | 0·0172 |
| Aluminium sulphate | Saturated | 0·0024 |
| Barium chloride | Saturated | Nil |
| Boric acid | Saturated | 0·0016 |
| Citric acid | 67·5 | 0·01169 |
| Lactic acid | Concentrated | 0·0087 |
| Magnesium chloride | 34 | 0·0057 |
| Nickel sulphate | 38·1 | 0·0125 |
| Oxalic acid | 8·8 | 0·035 |
| Potassium hydrogen tartrate | 0·37 | 0·0158 |
| Sodium carbonate | 17·6 | Nil |
| Sodium chloride | 26·5 | Nil |
| Tartaric acid | 53·5 | 0·0048 |
| Zinc chloride | 82·0 | 0·00195 |
| Zinc sulphate | 30 | 0·0001 |

with boiling solutions the safe limit of concentration is about 5%. Although phosphoric acid is listed in Table 2 as being corrosive to aluminium bronze, some compositions can be used satisfactorily in connection with this acid. In passing, it may be pointed out that when contemplating the use of aluminium bronze as a corrosion-resisting alloy under any given condition for which service data are not available, it is advisable to first make laboratory tests using the actual corrosive encountered, rather than a synthetic corrosive made up from laboratory chemical reagents.

## Applications under Corrosive Conditions.

While sundry applications of aluminium bronze are made specifically because of its high-tensile or compressive strength, or excellent resistance to alternating fatigue, these will not be considered here. There are numerous cases where both mechanical properties and resistance to corrosion are met by the use of aluminium bronze; in other applications the resistance to corrosion is the primary factor leading to the selection of an alloy of this type. At the present time aluminium bronzes are furnished as sand castings, permanent mould castings, sheet, rods, angles, pipe, tubes, wire, forgings, and such fittings as bolts, nuts, rivets, washers, lag-screws, and the like. Many types of castings are produced, and sheet is worked into various shapes by drawing and forming.

One of the most important present uses of aluminium bronze is in the construction of equipment for pickling steel parts in sulphuric acid. Tanks, crates, racks, and baskets, as well as hooks, slings, wire ropes, chain, and various tank fittings are made of this alloy. Some large racks are cast, and crates may be constructed of angles and sheet. Tanks are made of sheets and shapes welded together. Fig. 1 shows a pickling basket made of perforated sheet and strips, riveted together. Another application is for tank tie rods in the construction of wooden tanks used for holding sulphuric or hydrochloric acid. Aluminium-bronze bolts and screws are also employed in such tanks. Fig. 2 shows a tank fitted with aluminium-bronze trimmings. Equipment for the chemical industry, including pumps, stills, valves, autoclaves, and piping, is made of this alloy. Thus, pumps made entirely of aluminium bronze are used for the handling of sulphuric acid, particularly in pickling operations. In passing, it may be pointed out that it is of advantage to construct equipment exposed to corrosive influences entirely of the same material, thereby avoiding the severe electrolytic corrosion that occurs when two different metals are in contact. Pumps are made of castings and forgings of aluminium bronze bolted together with bolts of the same alloy. Reciprocating, rotary, and centrifugal pumps are made of aluminium bronze. Fig. 3 shows a centrifugal pump made of aluminium bronze. In some pumps the rods, valve-plates, and liners are made of aluminium bronze. Flanged and screwed valves are made in various sizes, particularly for use in acid-conveying systems—*e.g.*, in handling oil-refinery sludge acids. Fig. 4 shows a gate valve made in aluminium bronze.

Another use of aluminium bronze is in the construction of ventilating systems for ducts and fans. Ducts are made of sheet. Exhaust fans are made in standard types. Aluminium-bronze ventilating systems are used in pickling rooms, storage-battery rooms, rubber vulcanising plants, newspaper plants (over linotype melting pots), dry houses, laboratories, and other places for handling corrosive vapours. In cases where steel fans are completely destroyed in a relatively short time, aluminium-bronze fans may last almost indefinitely without painting or otherwise treating. Fig. 5 shows a "Sirocco"-type fan in aluminium bronze. Another application is in the construction of filter presses, for frames and rods—*e.g.*, for use in rayon plants where weak solutions of sulphuric acid are handled. Fig 6 shows a filter-press frame made of aluminium bronze. Owing to its high resistance to corrosion by sea water, aluminium bronze finds application in marine work for propellers, rudders, and various fittings. One of the earlier applications of aluminium bronze was for valves, fittings, and other parts in the paper industry where sulphite liquors are handled. Owing to the fact that this alloy tarnishes very slowly in ordinary air and retains its colour well in sea air it has been used to a considerable extent for making subsidiary coinage.

While the general field of application has been indicated above many other specific uses of aluminium bronze might be mentioned, and new uses as a corrosion-resisting material are continually being found.

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# The Progress of Arc Welding

By Edward Dacre Lacy.

## Ship Construction and Repair Work.

WITHIN the last twenty years or so, welding by the electric arc method has been accepted by industry as one of its most important production and repair processes. Before that time welding was employed principally to repair broken parts of machinery and other metal parts, but until comparatively recent years the value of welding as a standard method of joining metal pieces in general manufacturing was not fully appreciated. During the war, however, electric arc welding came rapidly into its own owing to the speeding-up of production in the shipyards, Government dockyards, and throughout the heavier industries.

At first this process was limited to use on small and less important parts, but as experience was gained, its field of application was greatly extended to heavier and more important construction and repair work. Welding is now employed in almost all manufacturing concerns for producing the smallest articles of everyday use to the largest steel constructed structures, such as ships, locomotives, tanks, and pipe-lines, and to a less extent in erecting metal bridges, factories, or general buildings.

Although electric arc welding in England is in a very different position from what it was a few years ago, progress is not so speedy as the exponents and advocates of this process would wish it : the reason for this relatively slow progress so far as ship construction is concerned may be stated thus :—

(1) The lack of skilled welders.
(2) The opposition of the trade unions.
(3) The inability to purchase the proper materials ; and
(4) The conservatism of shipbuilders and constructors ; ever since ships have been built of steel, ship constructors have been used to a riveted ship.

During and since the war the natural prejudice of shipbuilders has been gradually breaking down, and most naval architects now realise that electric arc welding can play a large part in the construction of moderate sized vessels. More skilled welders are now coming forward than hitherto, and, generally speaking, it has been found that a skilled workman, particularly a boilermaker or a blacksmith, who has necessarily obtained some knowledge of other welding processes, should become an efficient electric arc welder in six weeks. Welders are being trained as rapidly as possible in all parts of the world—that is to say, as rapidly as the supply of good teachers will permit,—but, given an intelligent man and good tuition, a year or two's practice at the work should convert pupil into teacher.

Until a few years ago it was difficult for shipbuilders to obtain the best materials for electric arc welding, and also very few had any knowledge of welding at all. But since the termination of the war, knowledge of welding has increased, largely owing to the good offices of manufacturers of welding plant and electrodes, who are always ready to give unstinted service and the benefits of practical experience, which is naturally of great value. Materials are now being made which enable any class of alloy, both ferrous and non-ferrous, to be satisfactorily welded, and new developments are being made every day by leading firms.

In spite of disadvantages, progress, if slow, is gradually being made, and as an industry electric arc welding is still in its infancy. Shipbuilders and ship repairers are now beginning to realise that much time can be saved by employing arc welding in place of riveting ; in fact, ship construction and repairs can now be carried out with all speed and efficiency by this means.

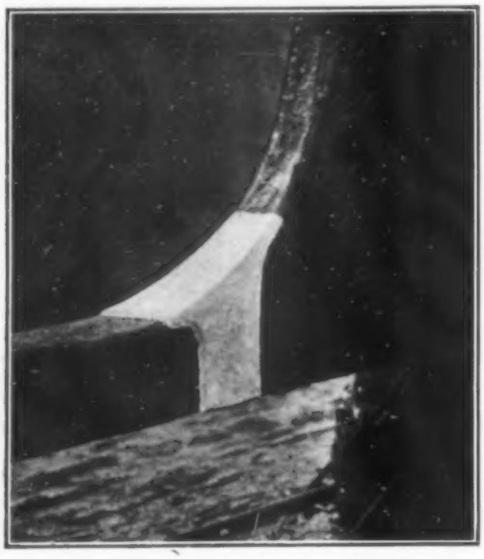
There is undoubtedly great scope in shipbuilding for the utilisation of electric arc welding, which has been found suitable for the building of smaller vessels, and can now be extended to vessels of larger size, as experience is gained, and as the processes of electric arc welding are perfected. Not only for structural purposes, but for the building of boiler and deck and below-deck machinery this process can be used, and it has now been proved beyond doubt that a welded joint is very much stronger than a riveted one. It should, indeed, be possible to do away with riveted joints altogether, and by welding a homogeneous whole may be obtained ; the ideal ship would be built in one piece, welding having joined all parts into one.

*Fracture in stern frame made ready for welding.*

In actual experience it is hard to show achievements obtained by the use of electric arc welding in shipbuilding, because no testing machine could reproduce complete stresses endured by a ship in service. The first all-welded ship to be built in England was a barge constructed at Richborough and welded by the Royal Engineers. This barge was designed for cross-Channel service, and owing to having carried all kinds of war materials, suffered from very hard usage. It was 126 ft. long, 16 ft. 4 in. in breadth, and 7 ft. 6 in. in depth. Up till 1924 the vessel was in the service of the Port of Queenborough Development Co., Ltd., whose engineer, Mr. J. W. Bruce, stated after an examination in May, that :—

" This barge has been thoroughly tested by me recently, and I find all streak-welded laps and joints, frames, web frames, beams, and half beams, and all welded parts in excellent condition. This barge, with others of the A.C. Type, has been subjected to very rough treatment and heavy service during the busy war period at Richborough. She consequently shows definite signs of same, but, nevertheless, remains in excellent condition, and quite tight when loaded. Up to the present it has not been necessary to have any work whatever done to the hull or deck. The vessel is in good seaworthy condition, and I consider her much stronger than riveted barges."

The next all-welded vessel to be built was the motor-ship *Fullagar*, whose dimensions were: Length, 150 ft.; breadth, 23 ft. 9 in.; and depth, 15 ft. 6 in. It is interesting to record that this ship was built to the classification of Lloyd's Register of Shipping, and may be said to have arisen out of a series of experiments on welding carried out by the Register. The vessel was built by Messrs. Cammell Laird and Co., Ltd., at Birkenhead.



*Fracture completely welded.*

Quoting from a paper read before the British Institution of Mechanical Engineers in 1922, Mr. A. T. Wall said :—

"This ship has been commissioned for about eighteen months, the welding employed for her construction has been proved highly satisfactory. She has carried several cargoes of steel plating and similar material, and has encountered heavy seas without showing signs of failure of any welded joint. At one time, in a collision, she received an indentation in her side without starting any welding. Lloyd's Register of Shipping recently examined this ship, and reported that there were no signs of weakness even at the break at the port of deck, which easily happens to riveted vessels of this class."

Since the war several all-welded ships have been planned, one by Sir J. W. Isherwood, who designed a modified longitudinal frame ship, the modifications consisting of the use of electric arc welding for the making of practically all joints, the design being in accordance with Lloyd's Register of Shipping rules for electric welded vessels. The design was such that no overhead welding was required for strength members; by using wide plating large portions of the frame would be welded to plates in the shop. This Isherwood design, which was prepared with the co-operation of Sir Westcott Abell, then Chief Surveyor of Lloyd's Register of Shipping, is such that any ordinary shipyard could readily handle the job. Another design was by Major James Caldwell, who prepared a design for an all-electric welded barge, using a conventional transverse frame ship design with certain modifications and details in the construction. This design was based on the experience gained from the building at Richborough of the cross-Channel barge described above. Major Caldwell stated that the principles governing the substitution of arc welding for riveting in the construction of a ship were as follows :—

(1) Obtaining equivalent strength.

(2) Minimum of overhead welding.

(3) Ease of repair.

In his "Notes on Welding Systems," Major Caldwell has given some interesting details regarding the comparative cost of electric welding and riveted barges.

In the labour, 245 man-hours were saved in the construction of the welded barge, more than 1,000 lb. of metal was saved by the substitution of welding for riveting, even greater economy will result when the design is modified to suit electric welded ship construction. The total cost of welding was £301, comprising electrodes (£178), electric current (£61), and labour (£62). The cost of assembling similar barges built in the same yard by ordinary method of construction, including riveting, caulking, and drilling, was £389 8s.; while in another yard, where ten barges were built, the average cost was £453 8s.

In a report from one of the Admiralty Dockyards, where the electric welding process has been extensively employed, it was claimed that electric welding, if applied instead of riveting, would reduce the cost of labour on the ship by 75 per cent.

Stronger steels have recently been introduced for shipbuilding purposes, the advantage of which is the reduction of deadweight without sacrificing strength. An example of such steels is "Ducol" steel, which contains 0·25% carbon and 1·5% manganese, and has a tensile strength of 40 tons, compared with 30 tons for ordinary ship-plates.

Welded joints with suitable coated electrodes, tested by Messrs. David Colville and Sons, Ltd., the manufacturers of "Ducol" steel, gave the following results :—

Tensile strength: 40·4 tons per square inch—fracture clear of weld.

*Extension.*—17% on 8 in. specimen.

*Analysis of Weld.*

| | |
|---|---|
| C | 0·215% |
| Si | 0·03% |
| Mn | 1·80% |
| S | 0·027% |
| P | 0·035% |

From the above results it is shown that the weld easily maintains the material strength, and is of the identical composition, containing neither a line of weakness nor electro-chemical corrosion.

*Singapore Floating Dock, equipped with a Portable Motor-Generator Electric Welding Plant.*

Electric arc welding has now been used for some years for ship repair, and its use for this purpose is becoming commoner day by day; in fact, it is very rare that any metal part cannot be repaired, so that it is in as good a condition as it was before the breakage occurred. In many cases the part which was originally on the weak side can be reinforced during the welding operation, and plant for this type of welding is now found in all shipyards and Admiralty dockyards. Its use in shipbuilding and repair works,

(*Continued on page* 64.)

# Principles and Uses of Wire Rope

## Part VII.

By Walter A. Scoble, D.Sc., M.I.Mech.E.

*Head of Engineering Department, Woolwich Polytechnic.*

*Adjusting the tendency of certain layers to twist. Different fibres used in the formation of rope cores.*

The only way in which twisting under tension can be eliminated is by balancing the torques in the two directions. Thus, in a locked coil rope, which is the only simple construction that can be made truly non-rotating, the layers of wires may be right and left handed, and so adjusted that the tendency of certain layers to twist in one direction is just balanced by the torque exerted by the other layers in the opposite direction. A more complex rope may consist of more than one layer of strands with the layers laid in opposite directions, in which case a balance of the torques may be effected.

It is worthy of note that the torque which is required to prevent a rope untwisting is not large—it is probably smaller than is generally realised. A rough calculation gives an idea of the magnitude of the restraining moment, although great accuracy cannot be expected. Consider the $6 \times 19$ rope of 2 in. circumference which has been dealt with. The rope diameter is $0 \cdot 640$ in., strand diameter $0 \cdot 212$ in., and the inclination of the strand at its centre is $19° \ 15'$. Assume a tension of 3 tons on the rope. If $t$ be the tension in a strand, $t \cos 19° \ 15' = 0 \cdot 5$, by resolving $t$ along the axis of the rope, and there is a component perpendicular to the axis which is $t \sin 19° \ 15'$, or $t \tan 19° \ 15' = 0 \cdot 1746$ ton. These forces may be assumed to act at the centres of the strands, at $0 \cdot 214$ in. from the rope axis; consequently, the total twisting moment is $6 \times 0 \cdot 1746 \times 2240 \times 0 \cdot 214 = 502$ lb. in. The writer has put small ropes under tension between ball-thrust bearings and has measured the torque required to prevent twisting, with results which agreed very well with calculations made as above.

This estimate of the restraining moment involves two factors other than the rope tension, namely, the tangent of the angle of the strand in the rope, and the radius to the centre of area of the strand section. Reduction of these factors lowers the torque. Thus, a longer strand lay reduces the tendency to twist, as does, also, a strand formation like the Keystone, which brings the centre of the strand nearer to the axis of the rope.

The length of the lay of a rope of given size not only affects its tendency to twist, it influences many other rope properties. Thus, it was found, when rope strengths were calculated, that the cosine of the strand angle was involved, from which it follows that when this angle is small, which means that the pitch is large, the rope should have a greater tensile strength. This fact may be regarded differently, it being appreciated that the strength of a rope is less than the aggregate strengths of the wires, because the wires and strands are inclined to the rope axis, from which it is realised that an increase of the rope pitch, which reduces the angle of the strand, leads to a smaller loss of strength, until, when the limit is reached and the pitches are infinite, the rope is replaced by a bundle of parallel wires which develop their full strength.

The two rope properties considered are both improved by an increase of the pitch, but other considerations impose a limit or operate in the opposite direction. It has been seen that ropes will unravel if the ends are not served, which shows that there is a tendency for the strands to unlay. This tendency becomes greater with longer pitch to the strand and sets a limit, but it seems probable that the pitch of a preformed Trulay rope can be somewhat longer than that adopted for a similar rope which is not preformed. The bending of ropes is a most important subject which will be fully dealt with later, but it may be noted that a reduction of the strand pitch makes a rope more flexible, and allows it better to withstand repeated bending. The extension under tension of suspension ropes for bridges and for ropeways should be small in order to prevent the sag from becoming excessive. This extension under tension is due partly to the stretching of the wire, with an added elongation which is due to the increase of the pitch of the strands, the helical strands behaving somewhat as springs. A simple way in which to think of this is to remember that the helical strands tend to straighten under tension, and the strands, when straight, have a greater length than the axis of the rope composed of helical strands. This second portion of the rope elongation is reduced when the pitch of the strands is increased, whereas for the supporting cables of suspension bridges it is often entirely eliminated by the use of parallel wires which are bound together to keep them compact, and, usually, to allow them to be covered as a protection against weathering.

### Rope Cores.

The cores for ropes are usually composed of some kind of fibre, and a similar material is used in some constructions as cores for the strands. It appears probable that the adoption of fibre for cores was connected with the history of ropes. Wire rope replaced fibre ropes for many purposes, and ropes of both kinds were, and still are, made by the same companies. New products frequently develop by easy stages from the old, an illustration of which is the early motor-car with a body like a governess car. It should not be assumed that fibre is the only, or of necessity the best material for cores; it is probable that its use was suggested by the fibre rope, that it has answered the purpose fairly well, and, if other materials have been considered, they have not met with general acceptance or their use has not been developed.

Many different fibres are available, and most rope makers have a definite scheme for their use in wire ropes which are intended for various purposes. Practice in this respect is by no means consistent, and it is justifiable to say that the subject of fibres requires further study and that alternative materials should be considered.

Standard specifications do not deal adequately with this question. Taking first the British specifications, that for crane ropes states that :—" The fibre used for the central or main core of the rope shall be new long fibre, good-quality hemp, manila, or jute, as may be specified by the purchaser." The writer was chairman of the sub-committee which prepared the specification, and so, perhaps, may be allowed to discuss and even to criticise this clause. In the first place it is unlikely that most purchasers are qualified to specify the core material to be used. Hemp is regarded as the best vegetable fibre, being strong, flexible, and durable. Manila hemp has remarkable tensile strength, and is particularly suitable for large fibre ropes, but it is stiff and woody and, in consequence, is unfitted

for use in small cores. The other hemps, including sisal, follow in order of usefulness and have considerable tensile strength. Jute finds considerable favour on account of its cheapness, but it is inferior to the hemps in both strength and durability.

The necessary properties for a core will be noted later, and the following facts have a bearing on these requirements. The fibre is spun into yarn, and a number of yarns are twisted in the opposite direction to form a strand. This corresponds to some extent to the laying of wires into strands and strands into rope for an ordinary lay rope. Greater twisting of the fibres hardens the yarn but reduces its strength and flexibility, the reductions being more pronounced with woody fibres than for those of finer texture. Yarns are sometimes treated with something of a tarry nature to enable them to resist the rotting action of moisture, but the tensile strength is reduced thereby. Manila hemp has a good natural resistance to the action of water.

The property which is definitely required in the specification is " long fibre," otherwise the clause affords little guidance on the necessary characteristics of a core.

The later British specification for lift ropes carries this question appreciably further and indicates other requirements. It appears to be desirable to include this in full :— " The central or main core of the rope shall be of sufficient size and density to afford full support to the strands."

The fibre used for the central or main core of the rope shall be new, acid free, long fibre, good-quality hemp, manila, or jute.

The purchaser may specify the material of the main core if he so desires.

The chief function of the core is recognised here, then the term " acid free " is added, and, finally, the purchaser is not required to specify the material, but he is given the right to do so if he wishes.

The core is in contact with the wires and the presence of acid leads to corrosion of the steel. The fibre itself may have an acid reaction, or acidity may possibly be introduced in the batching used in the preparation of the fibre, or by the interaction of the batching on the fibre. The internal corrosion of wire ropes is not uncommon, hence the matter dealt with here is of considerable importance.

### Specifications for Rope Cores.

The British specification for ropes for oil wells includes sisal for rope cores but prohibits the use of jute, indeed the clause is precisely similar to that adopted for winding ropes for mines, whereas the use of jute is permitted for haulage ropes. There is no corresponding clause in the specification for shipping ropes.

The United States Government Master Specification No. 297 puts the essentials differently, and is as follows :— " Fibre cores for wire rope shall be of the required material, either cotton or one of the hard fibres, as specified in the detailed requirements. The hard fibres are manila (abaca), java (African, Mexican or Yucatan), and sisal. Jute fibre shall not be used. A mixture of two or more kinds of hard fibre may be used. Fibre cores shall be of the best-quality fibre, thoroughly cleaned, and free from waste, evenly twisted, of uniform ply, and of good workmanship."

Each specification brings forward new points without being complete in itself. Cotton is admitted here in a master specification, and may be used for small ropes, such as those used on aircraft, but its cost is prohibitive for general use in large wire ropes. Materials are mixed for fibre ropes, and the practice is recognised and is permitted here for cores. Reference is made also to the twisting and to uniformity, which directs attention to these points although the treatment is inadequate, and is probably necessarily so.

The clause in the specification published by the American Petroleum Institute treats the core from a different standpoint. It states :—" For all wire ropes manufactured under this specification all fibre cores will be of hard-twisted, best quality manila, or Java hemp, or its equivalent. They shall be of uniform diameter and hardness, and effectively support the strands. No jute cores shall be used." The core is considered here as a bed for the strands and its hardness and uniformity are insisted upon, but several other matters of equal importance are not mentioned.

It will be well to review the characteristics of a satisfactory core. Naturally, its cost should be as low as possible when the required properties are ensured. The core should be hard enough to support the strands and to prevent them closing on each other, but the strands should bed into the core and be effectively supported. It has been seen that the core is indented by the strands and by the individual wires, and is squeezed up between the strands. It seems that the core should alter its shape somewhat under pressure without appreciable reduction of the density. Some cores are found to become soft when they are impregnated with a lubricant, and this is not permissible. The tensile strength does not seem to be important, although the core must stretch and stand bending without breaking. Long fibres and flexibility should meet these requirements with the vegetable fibres generally employed. Sometimes cores are found to perish and to break up into short lengths or even to powder. So the material is required to retain its properties under reasonable conditions and must not perish or rot. Acidity or marked alkalinity cannot be permitted, not only in the core itself, it must not arise by any action in the core or by the lubricant on the core. The core must withstand, also, considerable cutting action by the wire strands which move relatively to it.

## THE PROGRESS OF ARC WELDING

(*Continued from page* 62).

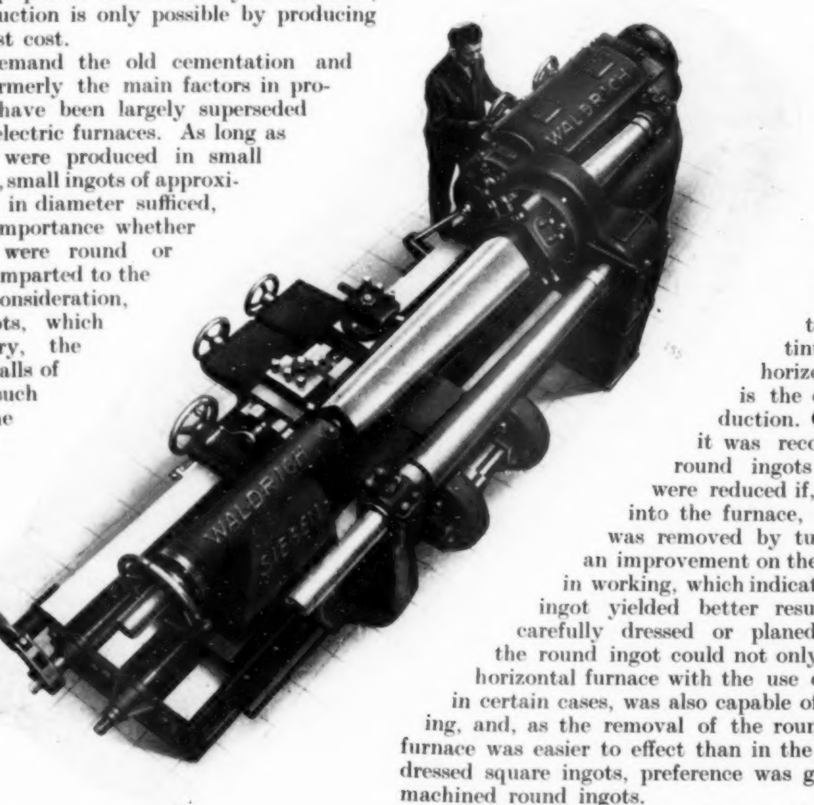
although extensively used, must be necessarily restricted, where it is used in any connection for structural strength purposes—in any plating except mild steel, in fact. It is not generally accepted to employ electric welding with " D " quality steel.

In the actual construction of a mercantile vessel electric welding can be used in many different connections ; for instance, in building up corner and angle-bars, this process is cheaper than forging them. Bolts can be welded on steel plating for deck plank fastenings, thereby obviating the necessity of piercing the decks and possible damage to fittings below where fitting-out work is well advanced. Further, in this connection, where water-tight compartments have already been water-tested, welding can be used instead of drilling, riveting, and caulking, and can be profitably used as the cost of a re-test would not be incurred. Welding can also be used for laying foot strips on deck plating to avoid slipping. For some years this process has been used in the manufacture of oil and water tanks for use on board ship. In building up pipe connections for pumping and draining systems, electric welding is of great assistance. Pipes with flanges loosely attached can be put into position temporarily, and the flanges and pipes can be set to correct position and levels, and just caught by electric welding, then removed and the welding completed. In many cases electric welding can be used in awkward corners where there is not sufficient space to rivet.

In repair work electric welding has been used extensively for some years, and in addition to those which have been described above, applying to shipbuilding, welding can be employed very largely in alteration work, to avoid the necessity of lifting large pieces of machinery to get in new fastenings, and for restoring corrugations of footplates and ladders by means of specially hard electrodes, thereby saving the expense of new footplates and new ladder treads. Again, electric welding can be used for reinforcing deck pipes and hawse pipes when worn thin with the rub of cables, and in the repair of small castings, and more particularly steel castings, and in connection with the inner bottom plating when it has been worn thin.

# Square Turning Alloy-Steel Ingots

IN no other branch of the iron and steel industry is the need for careful and thorough working methods greater than in the manufacture of high-grade steels. The enormous increase in mass production of ordinary steels has led to a corresponding increase in demand for these high-grade steels. With increasing production, methods have necessarily become more and more exacting in order to meet the increasing specifications and tests now being required for all kinds of alloy steels. To meet this demand adequately, and to be able to cope with it economically, the most modern plant equipment and machinery are essential, since successful production is only possible by producing the best at the lowest cost.



*View Showing the Cross-slide.*

With increasing demand the old cementation and crucible furnaces, formerly the main factors in producing alloy steels, have been largely superseded by open-hearth and electric furnaces. As long as these special steels were produced in small quantities in crucibles, small ingots of approximately 3 in. to 5 in. in diameter sufficed, and it was of little importance whether these small ingots were round or square. The shape imparted to the ingot required less consideration, as with small ingots, which were then customary, the cooling of the iron walls of the mould exercised such an acute effect on the cast crucible steel that both in round and square ingots crystallisation was substantially equal. To-day, however, this question has assumed considerable importance. Greater quantities of cheaper high-grade steel are now necessary, and the size of ingots has also necessarily increased, which has had the effect of bringing into prominence the question of shape of ingots used in manufacture. This has been uniformly solved in the mass production of ordinary steel, all large steelworks using only heavy, square ingots.

Technical considerations arose which caused a deviation from the development from mass steel production. In ordinary steelworks the crude ingots are used in their original state, with their casting skin exactly as it was immediately after drawing. In the production of high-grade steels, however, defects in the casting skin gave rise to inferior finished products, and the greater the necessary number of working stages the worse was the result. In mass production of ordinary carbon steel the deleterious influences of a defective casting skin in the ingot could easily be overcome, as a welding heat could be imparted to the periodically charged reheating furnace, which sufficed to eliminate any inner or outer defects in the ingot, so that, in spite of a faulty ingot, it was still possible to obtain an acceptable finished product. This was also attempted in the manufacture of high-grade steels, but with catastrophic results, as the majority of these steels cannot be welded, so that the percentage of rejected materials steadily increased.

Modern science, however, soon discovered the cause, and to determine whether a particular grade of alloy steel can be heated in the furnace above 1050° C., so as to prevent the steel reaching the subsequent working phases in burnt or cold state. Special steels of all kinds can only be heated very gradually, which results in greater losses by oxidation in the continuously charged horizontal furnaces than is the case in mass production. On the other hand, it was recognised that with round ingots these difficulties were reduced if, prior to charging into the furnace, their casting skin was removed by turning. This was an improvement on the experience gained in working, which indicated that the square ingot yielded better results if previously carefully dressed or planed by hand, while the round ingot could not only be fed into the horizontal furnace with the use of less force, but, in certain cases, was also capable of more rapid heating, and, as the removal of the round ingot from the furnace was easier to effect than in the case of the hand-dressed square ingots, preference was generally given to machined round ingots.

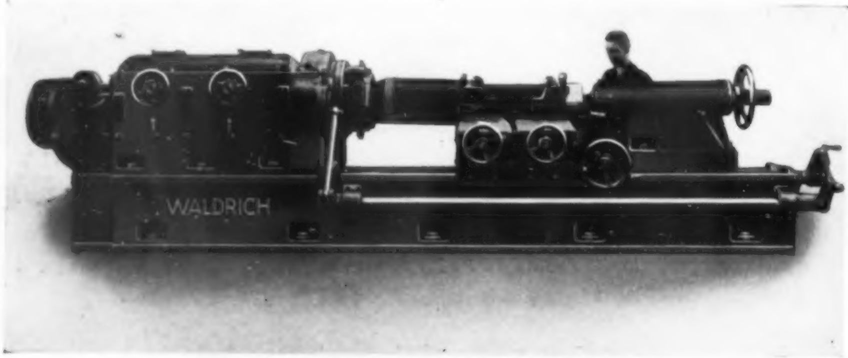
With the increase in size of ingots for high-grade steels it was recognised more acutely that finished products from angular ingots produced less waste and better material, quite apart from complaints regarding longitudinal cracks, and, in consequence, practically all large steelworks now adhere to the square ingot for all weights.

To get the best results from square ingots it has been proved that it was necessary to remove the usual defects from these ingots. The removal of the casting skin and other more deeply rooted surface cracks was essential, and the machining was required to be done as cheaply and effectively as the standard lathe prepared round ingots. This problem has been solved by the square turning lathe, built by Messrs. H. A. Waldrich, Siegen, which has proved an important economic factor in many works producing alloy steels. This machine is essentially of sturdy construction, and the substantial bed carries a special form of slide.

The machining of the ingot is effected by means of an ordinary cutting tool, but in operation the circumferential

speed of the ingot changes according to the lateral surfaces or corners, and in consequence the cross-slide with the cutting tool has a reciprocating trajectory. It has the advantage of working automatically, and one man can operate several machines at once, the removal of the casting skin of the ingot being thus rendered considerably cheaper.

In operating the square turning lathe the ingot is secured to the face-plate of the headstock by means of a special grip, while the tailstock supports the other end. self-acting automatic feed in the longitudinal direction of the machine by means of a ratchet gear, permitting a a very fine feed and adjustment suited to different hardnesses of material. Of massive construction, the headstock gives eight different speeds to the face-plate, being actuated by sliding gear wheels, all of which are machine cut from high-class forged steel blanks. These wheels run in oil-baths to ensure efficient lubrication. The reciprocating tool-rests are provided with automatic lubrication, thus lengthening the life of all parts concerned.




*The Machine Set Up, with Two Tools in Operation.*

The machine carries two or three tool-rests, according to the length of ingot for which the lathe is intended, and either two or three tools may be used at the same time, being clamped to suit different lengths of the ingot. The movement of the tool-rests is controlled by a template, corresponding in shape with the required shape of the ingot, which is driven by a back gear connected with a crown-wheel on the face-plate. In machining, a uniform thickness of material is removed from the ingot over its entire length which reduces the loss of material to a minimum. Templates are easily interchangeable, and produce the most desirable detailed shape. The main slide of the machine is readily adjusted by means of a small motor by which the slide is quickly returned to its starting-point after finishing the cut.

In this machine the saddle supports are fitted with a

It is of interest to note that in square-turning nickel-steel ingots approximately 44 in. long, and about 10 in. to 11 in. square, the time occupied to complete the machining was about 40 to 48 minutes, using two tools, and including setting up and taking down. In a works dealing with these ingots six square turning lathes are in operation, 10 ingots are machined on one machine in 8 hours, and one man serves two machines.

This machine provides the more modern way of freeing the ingot from surface cracks and blemishes quicker and more economically than any other method previously devised, and since it has been designed as a result of many years' experience, and with the close co-operation of the steel-worker, it is specially suited to the needs of steelworks dealing particularly in alloy steels.

## Modern Steel Pouring Practice

(*Continued from page* 45).

to the sides of the mould of the liquid metal and to a smaller extent by the cutting away of the mould bottom. On further filling of the mould the kinetic energy given out on impact with the mould bottom is absorbed by the excessive churning of the previously poured liquid. Marked deterioration of the moulds, splashed ingots, and a tendency towards blowholes are the results which directed attention to "tun-dish" casting as a means for the slower teeming of the ingots and the reduction of the velocity of the stream from the nozzle produced by the pressure of the steel in the ladle.

### "Tun-dish" Casting.

In this method the liquid metal is first poured into a small auxiliary ladle having from two to six nozzles and accurately centred over the moulds to be filled. The nozzles in the tun-dish are carefully chosen, so that there will be smooth delivery of metal to the moulds without excessive opening and shutting of the ladle stopper, and a small head of metal is maintained in the dish in order to produce a fully shaped stream from the nozzles. Under these circumstances, splashing of the moulds is considerably reduced, and, owing to the cooling effect of exposure of the metal to the atmosphere, piping of the ingot is not so great. The method lends itself to the conditions in modern high-output melting shops, and, compared with bottom casting through runner bricks, shows marked economy. The ingots have, however, an erratic tendency to vary considerably in length, and some method of inclining the dishes so as to promote the filling of any particular mould is necessary.

A method of earlier origin is that of pouring the liquid metal down a centrally placed pipe or "guit," through fireclay runner bricks, and into the bottom of the moulds by means of openings in the runners. By this means ingots could be poured as slowly as required, and the violent agitation of the partly poured ingot by the stream of metal in top pouring was avoided. This resulted in a very smooth surface on the ingot with consequent improvement in the finished material, but the interior of the ingots was often found to be either piped in the lower sections or to be unsound. Marked reduction in the amount of piping was brought about by the use of wide-end-up moulds, as previously described for top casting, and the closed bottom type with a fireclay nozzle gave further advantages.

A point sometimes overlooked is the correct size of nozzle and diameter of central casting pipe. A small amount of consideration will readily show that where the ladle nozzle is smaller than the pipe cold air will be injected into the centres of the ingots. Careful feeding of molten material to the ingots at the end of the casting is very essential if hollow ingots are to be avoided. Should one ingot be rising at a slower rate in the mould than its neighbours and pouring down the central guit has stopped, feeding of the smaller ingot will proceed from the higher, liquid steel flowing from one to the other until the pressures are the same. One of the most prominent objections raised by engineers against this method of casting has been that of inclusions in the ingot, which were usually ascribed to erosion of the runner bricks. Most high-class steel-makers now employ the maximum of care in setting up the clusters, vacuum-clean the moulds and runners, and use only those runner bricks made from the most resistant fireclays.

# Effects of Nickel upon Malleable Cast Iron

ALTHOUGH nickel is known to be beneficial to ferrous products generally, very little data have been published upon the effects of this element when alloyed to malleable cast iron, and the following experiments conducted by J. V. Murray, who has gained an award from the Staffordshire Iron and Steel Institute for his original research work, have a special interest.

Test bars were cast, the dimensions being those required according to B.E.S.A. specification. As the B.E.S.A. only call for tensile, elongation and bend tests, as given below, these were carried out on both cupola and crucible melted metal.

B.E.S.A. No. 309/1927. This specification demands the following minimum :—

Ult. tensile strength, 20 tons per sq. in., with

Elongation not less than 5·00% on 2 in. on a round bar of 0·564 in. diameter ; together with a

Bend test 45° on a bar 8 in. long, 1 in. wide, and ⅜ in. thick, without showing cracks or flaws.

The pig irons were those normally used in the industry, refined, malleable, and ordinary blast furnace malleable pigs being chosen. All the experiments were conducted on a commercial basis, the pig irons being chosen solely in order to produce white castings, no special choice being made, and the ordinary mixing by calculation being followed. The annealing was carried out in the usual way, except where described, being controlled by a Fery pyrometer.

The first experiments were cupola-run metal, the nickel, in the form of "F" shot, being first tried at the bottom of a hot ladle and molten metal run into it. This was not entirely satisfactory, and finally it was decided to place the nickel shot right in front of the tap-hole as the metal was being tapped. The whole of the test was done in triplicate.

From chemical considerations and calculations there was no loss of nickel—*e.g.*, 1·00% was calculated and added. The chemical analysis gave 1·02% Ni. All the bend-test bars were bent until fractured, the results being given in Table I.

TABLE I.

CUPOLA-MELTED SERIES.

| Chemical Analysis, %. | | | | | Physical Tests. | | |
|---|---|---|---|---|---|---|---|
| Si. | S. | P. | Mn. | Ni. | Tensile Strength, Tons per Sq. In. | Elongation % on 2 in. | Bend Test. |
| 0·43 | 0·14 | 0·11 | 0·14 | Nil | 21·3 | 6·5 | 67° |
| 0·59 | 0·18 | 0·08 | 0·12 | 0·51 | 21·7 | 5·0 | 46° |
| 0·45 | 0·12 | 0·07 | 0·11 | 0·78 | 22·5 | 4·2 | 43° |
| 0·52 | 0·18 | 0·07 | 0·05 | 1·02 | 25·4 | 4·5 | 33° |
| 0·56 | 0·18 | 0·08 | 0·12 | 1·53 | 22·5 | 3·5 | 33° |
| 0·73 | 0·17 | 0·09 | 0·14 | 2·59 | 25·3 | 3·5 | 24° |
| 0·80 | 0·18 | 0·07 | 0·14 | 3·06 | 21·9 | 2·5 | 16° |
| 0·78 | 0·16 | 0·08 | 0·15 | 3·42 | 17·1 | 1·8 | 2° |
| 0·77 | 0·19 | 0·07 | 0·14 | 3·53 | 13·6 | 1·2 | 0° |

### Consideration of Results.

Nickel in whiteheart malleable, when run from a cupola furnace, indicates the following :—

*Tensile Strength.*—The effect of Ni increases the T.S. of the casting up to about 1·00%, after which amount there is a reduction to approximately 1·75%. From this amount the strength increases with increase of Ni until primary graphite is deposited at just over 3·00%. The increase of graphite speedily decreases the strength according to the amount and size present.

*Elongation.*—There is a slight decrease up to about 1·5%, when the values remain fairly constant up to about 2·75%, when there is a speedy fall.

*Bend Tests.*—The effect of Ni appears to decrease the bends values. Up to 2·75% the fall is gradual, but after this descent is very rapid.

These results must be considered in the light of an increase of carbon, which, together with an increase of Si from the "F" shot would tend to make the iron grey.

A number of casts were made in crucibles in the usual commercial manner. Selected pig irons were melted, and the desired amount of "F" shot added. The castings in the form of test bars were then treated exactly as before. In some of the melts the "F" shot was placed cold in the ladle and melted with the iron. No difficulty was experienced during these experiments.

The chemical analysis and mechanical results are given in Table II.

The results of the tests in this series may be summarised :

*Tensile Strength.*—Nickel, when added in the crucible to malleable cast iron up to 1·00% increases the tensile strength of the castings. Then there is a reduction, after which the strength rises according to the amount present. This increase in strength is suddenly terminated as graphite makes its appearance, and a great reduction takes place as in the cupola series.

*Elongation.*—The elongation is reduced on adding small amounts of nickel, but when 1·00% is present there is a great increase, after which any further increase reduces the elongation.

*Bend.*—Varying results were obtained with additions of nickel, but at 1% a good increase was recorded. Increase of nickel reduced the values afterwards, but at 2·5% this increase was noted again.

One particular result was noticed. No. 5 series containing 3·06% Ni was very springy and resilient. It bends far more than was recorded after fracturing.

### General Conclusions.

The best all-round mechanical results are found when the Ni content is about 1·00%. From this amount upwards the general values decrease. Whilst in practice the tensile strength can be raised by adding more nickel, the other

TABLE II.

CRUCIBLE MELTED SERIES.

| Chemical Analysis, %. | | | | | Physical Tests. | | |
|---|---|---|---|---|---|---|---|
| Si. | S. | P. | Mn. | Ni. | Tensile Strength, Tons per Sq. In. | Elongation, % on 2 in. | Bend Test. |
| 0·64 | 0·18 | 0·07 | 0·18 | 0·27 | 26·7 | 4·0 | 81° |
| 0·54 | 0·18 | 0·05 | 0·16 | 0·55 | 24·1 | 4·3 | 60° |
| 0·55 | 0·12 | 0·06 | 0·20 | 0·74 | 25·4 | 4·2 | 35° |
| 0·74 | 0·09 | 0·06 | 0·22 | 0·98 | 25·4 | 9·3 | 53° |
| 0·68 | 0·16 | 0·07 | 0·20 | 1·33 | 20·3 | 2·3 | 23° |
| 0·66 | 0·14 | 0·06 | 0·19 | 1·76 | 27·3 | 4·2 | 27° |
| 0·66 | 0·16 | 0·10 | 0·17 | 2·59 | 28·3 | 3·2 | 52° |
| 0·68 | 0·11 | 0·09 | 0·23 | 2·71 | 27·3 | 5·2 | 37° |
| 0·56 | 0·15 | 0·07 | 0·14 | 3·06 | 27·4 | 3·0 | 54° |

values decrease. The amount of nickel which can be used in malleable work is limited, about 3·00 being the limit. More may be taken if the carbon or silicon is reduced. 1·00% Ni in malleable appears to be a critical composition, giving critical points in mechanical values.

Nickel in malleable iron, whilst making the iron stronger, has the effect of precipitating graphite, and any segregation of nickel will have the same effect.

Metallographical investigations may be briefly summarised as follows :—The greatest effect of Ni in malleable cast iron appears to be upon the condition of the pearlite. Small amounts of Ni refine or lessen the size of the pearlite plates. Increased amounts cause the pearlite to coalesce somewhat. With 1·00% Ni the structure of the pearlite was exceedingly fine. Beyond this amount the zone of ferrite from the edge decreases, whilst the pearlite becomes troostitic in character, increasing in intensity up to 3·06 when the eutectoid is almost an emulsion. When graphite flakes are thrown down the pearlite is almost normal again.

Evidence is shown that Ni tends to stabilise pearlite by preventing its breakdown during the annealing operations. It does not inhibit the breakdown, but retards it. Nickel appears to assist the breakdown of eutectic and secondary cementite, but does not influence the removal of carbon nodules after breaking down and refining the structure.

It is suggested that with 1·00% nickel the increases in tensile, bend, and elongation values are due to :—

1. Increased amount of pearlite present due to this pearlite being more stable, resulting in—
2. A more homogeneous structure—*i.e.*, no decarburized edge.
3. Finer structure of the pearlite, especially at the core.

These conclusions are supported by the microphotographs.

*Cupola v. Crucible.*—The difference between cupola and crucible cast bars may be explained by the pick up of carbon during melting in the cupola, although the method of melting is bound to cause some of them.

Both cupola and crucible bars show the best all-round properties when they contain about 1·00% Ni. The tensile strength increases as the Ni is raised up to the limit when graphite makes its appearance. This increased strength is accompanied by the refining of the pearlite, which finally (just before graphite makes its appearance in the original hard casting) becomes a mass of emulsion.

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# Small Induction Furnaces for Laboratories

In addition to the larger coreless induction furnaces of improved design developed by the Metropolitan-Vickers Electrical Co. for melting iron and steel and non-ferrous metals in commercial service, this company has also developed small induction furnace equipments which are particularly suited to laboratory work. The latter development was carried out originally to meet the needs of the company's own research work, but the design was later commercialised, and equipments supplied to the Universities of Manchester and Sheffield have been in successful operation for some time. An equipment of similar type, but of somewhat larger size, has now been ordered by Imperial Chemical Industries, Ltd. for use in the research laboratories of the works of Brunner Mond and Co., at Winnington, near Northwich.

The furnaces of this type have been developed in a range of sizes. The equipment ordered by Imperial Chemical Industries, Ltd., is designed to melt a charge of 20 lb. of metal and is rated at 20 kw. The equipment supplied to the University of Manchester is designed for a charge of ½ lb. to 2 lb., and is rated at 5 kw. Two equipments at Sheffield University are of rather smaller size, and are used for melting charges of a few hundred grammes of metal in vacuo. In all cases the supply of power at high frequency for operating the furnace is obtained by means of a water-cooled oscillator valve. The development has thus an additional interest as an example of the use of thermionic valves for industrial work.

The use of an oscillator valve which gives a frequency of about 500,000 cycles enables the furnaces to melt very small charges. While it is possible to melt a ¼-ton charge of steel with power at 500 cycles, charges of a few grammes require very much higher frequency. In laboratory furnaces, especially when working with rare or costly metals, it is very desirable to be independent of any size restrictions imposed by purely electrical considerations, and so it is essential to provide a frequency which will melt all charges from a few grammes up to several pounds.

The furnaces will melt charges up to ½ lb. in 2 to 3 minutes. The normal full charge is melted in 20 to 30 minutes. All the furnaces will melt quantities up to about twice their normal charge provided that a correspondingly longer time is allowed for the operation. The only limit to the temperature attained in small charges is that imposed by the melting point of the refractory container, and within this restriction any metals can be melted. So great is the rate of energy input that a ½-lb. charge of steel will actually evaporate if left in the furnace field for 5 minutes. The power consumption on the larger charges of steel is only about 0·5 kw. hr. per lb. of charge, and correspondingly less for metals of lower melting point.

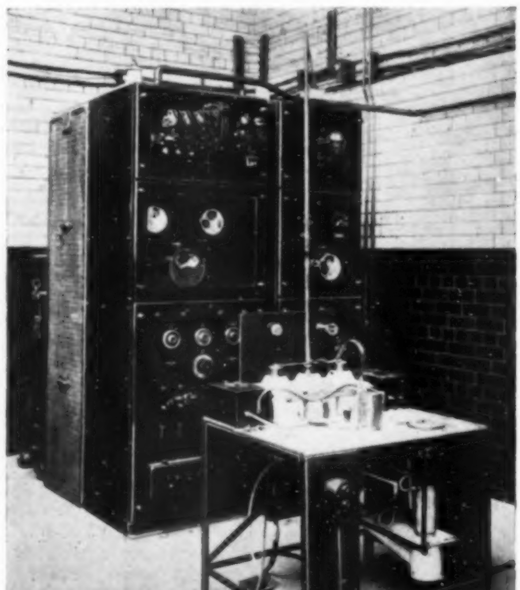


*Fig.* 1.

Fig. 1 shows the furnace equipment installed at the Manchester University, while Fig. 2 shows a 10- lb. ingot of steel being poured from a furnace in the Research Department of the Metropolitan-Vickers Electrical Co. In each case the furnace proper consists of a water-cooled coil, within which is placed a crucible containing the

metal to be melted. In Fig. 1 the coil is seen on the table. In Fig. 2 it is seen equipped with the tilting gear which is provided in the larger sizes. In addition to the actual furnace coil Fig. 1 shows also the incidental equipment, which consists of a high-frequency valve oscillator set and a three-phase valve rectifier set, together with control gear, indicating instruments and protective devices.


*Fig. 2.*

The right-hand cubicle contains the water-cooled oscillator valve together with its associated high-frequency and filament-supply circuits. On the front of the panel are a voltmeter, a rheostat for the valve-filament circuit, and tapping switches for varying the inductance of the grid coil to suit that of the furnace coil which is being used.

The left-hand cubicle contains the three-phase valve-rectifier unit, to which power is supplied at 10,000 volts by a transformer installed behind the cubicle. At the top of the panel are the main contactor and the filament-circuit contactor, which are operated by means of the push-button seen below. The high-tension supply is alternatively controlled by means of the push buttons on the furnace table. The panel also carries a filament voltmeter and rheostat, a voltmeter and ammeter for the high-tension current, and the protective relays.

At the back of the furnace table are the tuning condensers and a panel, on which is mounted a neon lamp to indicate when the set is oscillating, and an ammeter which shows the current in the oscillatory circuit. The provision of complete equipment of indicating instruments adds considerably to the usefulness of the equipment, as it enables the conditions to be checked and reproduced when required.

The protective devices include a filament-voltage relay, which protects the rectifying valves by preventing the application of the high-tension supply unless the filament voltage is at a correct value. Each rectifying valve is individually protected by an overload relay, these relays also serving as a general protection against overload on the equipment. A relay is provided in the water-circulation system, which trips the contactors of both the main and filament circuits in the event of failure of the water supply. The equipment is thus self-protecting, and the operator is enabled to give his undivided attention to the metallurgical aspect of the work.

A vacuum-pump equipment forms a useful accessory to the set, enabling melts to be made in vacuo. The pump equipment is conveniently installed beneath the furnace table, as shown in the illustration, facilitating connection with a short pipe and a minimum of jointing. The equipment can also be easily arranged for making melts in an atmosphere of inert or other gases.

Metrovick furnaces of this type have been satisfactorily used for a variety of research work. An example is an important investigation carried out at Sheffield University on the influence of Zirconium upon metals with which it is alloyed. A description of the work done and the equipment used in this investigation is given in a paper which was read before the Institute of Metals.* It is interesting to note that the weight of the alloys agreed so closely with the weight of the constituent metals (within 0·3%), that charges as small as 10 to 30 grammes could be used without sacrificing the accuracy of the work.

## Electrode position of Copper-Nickel Alloys.

QUANTITATIVE data on the factors controlling the percentage composition of an electrically deposited alloy are meagre except for a few isolated binary and ternary systems. The study of the deposit obtained from the copper-nickel system is the first of a series of studies in progress on the factors affecting the percentage composition of the metallic deposit obtained from solutions containing ions of two or more of the heavy metals. The results were given in a paper presented at the general meeting of the American Electro-chemical Society by L. E. Stout, O. G. Burch, and A. S. Langsdorf.

In the experimental work the alloy was deposited on Armco ingot iron cathodes from plating baths of known percentage composition, under controlled conditions of temperature and current density. The plating cells used were hard rubber battery jars, each having a capacity of about seven litres. The anodes employed were bars of electrolytic copper and bars of nickel (99 +). The cathode area was 28 sq. in., and the anode-cathode ratio was 2·5 : 1. The distance between anode and cathode was 2·25 in., and an interpole motor generator set furnished direct current to the system.

The chemicals used in this work were of the highest purity obtainable. Copper potassium cyanide analysed 19·5% copper and 12% moisture. It was qualitatively free from carbonates and sulphates. Nickel cyanide analysed 99·2%, $Ni(CN)_2.2H_2O$. Potassium cyanide showed 97·8% KCN with 0·02% chlorides and 0·002% sulphates.

The plating solutions were prepared by dissolving copper potassium cyanide and nickel cyanide in solutions containing just enough potassium cyanite to render a clear solution. These solutions were then diluted to a volume of five litres, and were not boiled before use in plating. The free cyanide content of the solutions was determined by diluting a 10 cc. sample with distilled water to about 50 cc., adding 10 cc. of a solution of potassium iodide and titrating with 0·1N silver nitrate solution, until a faint precipitate remains after vigorous shaking.

Considerable difficulty was experienced at first in the analysis of the deposits. This seemed to be due to the formation of oxides on the surface of the deposit, and to the difficulty of chemically stripping a high percentage copper alloy from iron as a base metal. As a result of careful study it was concluded that alloys of nickel and copper may be plated from baths containing mixtures of their potassium cyanide complexes, and the percentage composition of the deposited alloy depends upon the metal ratio of the bath, upon the cathode current density, and upon the temperature.

It was further concluded that an increase in the copper content of the bath increases the copper content of the plate, but to a much smaller degree than that indicated by the metal ratio of the bath. The ratio of copper to nickel in the plate increases linearly with the temperature. High cathode current densities encourage the formation of plates of high copper content. Baths of low free cyanide contents should be used to increase the rate of deposition.

* The Alloys of Zirconium, by T. E. Allibone, M.Sc., Ph.D., and C. Sykes, M.Sc.

# Review of Current Literature.

## Electroplating with Chromium, Copper, and Nickel.

As a commercial proposition chromium plating was practically unknown about five years ago, although in the laboratory it had been of academic interest for a long time. Its use has, however, made remarkable progress since its commercial inception. Chromium plating has become a factor of growing importance in the war against wastage of metals as a result of corrosion. The remarkable progress made in the process in such a brief time is such that articles that have been plated with this metal are rendered absolutely untarnishable, and, in consequence, its use has made rapid strides in sanitary fittings, motor-car fittings, and tableware, besides a host of other purposes. Mechanical, electrical, structural, and civil engineering have all found the hardness of chromium to be of great service because of its resistance to abrasion and erosion. The cotton, wool, silk, artificial-silk, and general textile industries have recognised its property of high resistance to corrosion, from which they usually suffer. Glass manufacturers and users of all kinds of dies have adopted the process to their great advantage.

As a result of the progress in the use of chromium plate, a demand has arisen for information regarding the process, and this work by Benjamin Freeman and Frederick G. Hoppe has been written with a view to meeting this demand. It is rarely found expedient to apply chromium plate directly to the base metal unless the metal to be covered is itself non-corrosive, such as copper or nickel. Thus, if iron or steel is to be chromium-plated, it is in many cases advantageous first to apply a copper or nickel plate, as these metals form a better protective coating. The authors recognise that any work on chromium plating would be incomplete without reference to the allied subjects of nickel and copper plating. In addition, the operation of polishing is given consideration. This is a necessary addition, as in deciding the degree of hardness the chromium plate should have, the state of final brilliance must be considered, and if the current is very high in the bath, or the immersion a specially long one, the plating will be very hard, producing a matt surface which can be buffed bright only after prolonged polishing. It is a matter of commercial importance that the extreme brilliance of chromium plate can only be economically obtained at a certain expense of hardness, and a consideration of polishing has an economical value in dealing with the commercial process. Apart from the fact that the hardness of the chromium plate influences polishing conditions, it is characteristic of this kind of plating that it follows faithfully every contour of the surface to be plated, and, in order to have a brilliant finish, the surface of the article must be highly polished before plating with chromium.

The authors have discussed the electrochemical principles involved in plating in a manner sufficiently comprehensive for a work of this nature, but the reader will find a knowledge of chemistry necessary to the proper assimilation of the information. In regard to the actual processes of plating with nickel, copper, and chromium, the greater attention has been given to chromium plating, and while a knowledge of the principles of electrodeposition of copper and nickel is fairly common, there are many differences in the process of chromium plating. In both copper and nickel plating the anode consists of the actual metal to be deposited, and as such is called a soluble anode; in chromium plating, however, an anode of lead or iron is used—lead being generally preferred,—the chromium deposit being supplied from a solution of chromic acid in the bath. The cathode which is used in the acid bath is always the article to be plated, as in the case of copper or nickel; but owing to the ready manner in which copper or nickel can be deposited, inaccessible places can all be covered with the required deposit. In chromium plating the difficulties are greater, as, owing to the rapidity with which hydrogen is liberated during electrolysis, considerable interruption to deposition can occur on any but an open surface. In consequence, the undersides of collars, shoulders, beadings, ledges, etc., will receive an inadequate deposit unless special precautions are taken.

The difficulty in all cases is overcome by using an anode specially shaped to the contours of the surface, and is dependent upon the skill and ingenuity of the person responsible for wiring the job. It can be assumed that chromium plating is more complicated than either copper or nickel plating, and although this form of plating is comparatively in its infancy and new methods may be devised, this work will assist in a clearer understanding of the process.

It is interesting to note that the question of ventilation has not been overlooked. It is, of course, essential to adopt a system which will prevent the chromic-acid spray from getting into the atmosphere of the plating room. The authors consider a system of cross-ventilation to be the most effective, which consists of air ducts placed along the top sides of the plating tank and connected with a blower of sufficient capacity.

An appendix refers to electroplating chemicals and other useful information necesaary to the consideration of electrodeposition, and the authors have added a bibliography to assist readers in the further consideration of the subject from previously written work.

By Benjamin Freeman, Ph.D., and Frederick G. Hoppe. Published by Prentice-Hall, Inc., New York, and Sir Isaac Pitman and Sons, Ltd., Kingsway, London, W.C. 2. Price 21s. net.

# Catalogues and Other Publications.

We have received a useful folder briefly indicating special features, applications, general uses and availability of Monel metal. It draws attention more particularly to the need for reliable bolts, rivets, etc., on appliances and structures exposed to corrosive attack, on fast moving machinery involving heavy stresses, and on structures subjected to high temperatures, and asserts that Monel metal is ideal for the purpose.

Further particulars are available on application to Messrs. Monel-Weir, Ltd., Cathcart, Glasgow, who have complete facilities for manufacturing articles and supplying material.

We have received a very comprehensive catalogue from Joseph Foster and Sons, Ltd., the old-established firm of power plant manufactures, which indicates in no uncertain fashion that they are modern in their outlook. It is sometimes said that skilled craftsmanship, setting its own standard of achievement, is unsatisfied with anything short of perfection, yet, while it falls short in its striving, it succeeds far beyond the reach of ordinary accomplishment. This thought is forced upon us in perusing the history of this firm together with the elaborately illustrated account of their products. They evidently possess an organisation which embraces a staff of expert engineers and a works equipped with modern machinery in order to cope with large contracts, such as complete power plants, including boilers, economisers, separators, pumps, $CO_2$ recorders, coal and ash handling plant, feed water softening equipment, etc. This artistic book can be obtained on application to the firm at their Soho Foundry, Preston.

One of the most notable advances which has taken place during recent years is a result of a development of the steam turbine. This principle of motive power is being used with increasing success for generator sets. Sets of simple operation of low first cost and high fuel economy were only possible after a lengthy period of careful design and experimental investigation. We have received a very interesting brochure giving useful information on self-contained turbo-generator sets which illustrates the wonderful strides being made by this firm in producing these power units of simple yet compact design, and applicable for a wide range of purposes. These self-contained turbo-generator sets have been developed not only as high-power units but also as reducing pressure sets, having special features of automatic control designed to pass out steam for heating requirements or for process work. Possible users of turbo-generators will be particularly interested in the brochure which is available on application to the Metropolitan-Vickers, Ltd., Trafford Park, Manchester.

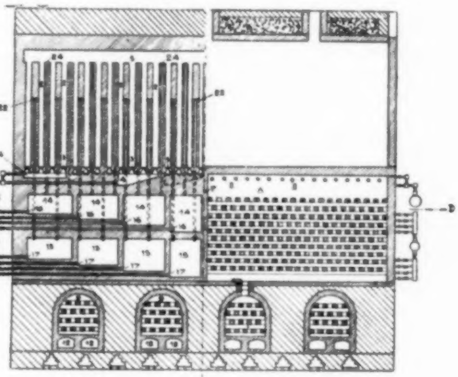
# Some Recent Inventions.

## COKE OVEN IMPROVEMENTS.

THERE are a number of horizontal coke ovens with vertical flues in which the heating flues of the side-walls receive the gas through a number of chambers, each of which is fed by a distributor. In ovens made of silicious and aluminous bricks it is important that the gas should be burned at the lower part of the heating flues with an excess of air in order to avoid a fusing of the bricks.

Modern ovens made of silicious bricks make it possible to increase the temperature in the heating flues appreciably, and under these conditions it has now been found useful to effect the combustion of the gas in the flues in a different manner. As the height of these ovens is greater, it is advantageous to effect the combustion of the gas admitted into the heating flues in a progressive manner. At the lower part of these flues the mixture of gas and air does not contain an excess of air, but rather an excess of gas, and this excess of gas is burned at various levels of the heating flues by successive inlets of air which finally give products of combustion containing only a small percentage of non-combined oxygen.

*Fig. 1.*



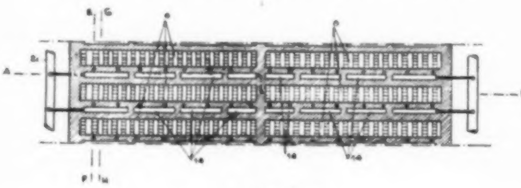


*Fig. 2*

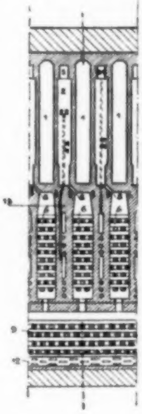


*Fig. 3.*

A new arrangement of coke ovens has been devised which enables the successive combustion of the gas, in the heating flues of modern ovens made of silicious bricks, to be effected in a more rational manner.

The admission of gas into the various heating flues is still regulated by means of the gas chambers, but in the wall situated between the individual regenerators of the ovens, air expansion chambers are placed, by means of which the primary combustion of the gas at the bottom part of the heating flues can be followed by several successive combustions at various levels of the heating flues of the side-walls, and each of these air expansion chambers is connected with several auxiliary flues, opening at the desired level of the heating flues, and with a distributor connected with a pipe containing air under pressure.

To each gas chamber corresponds a certain number of air expansion chambers, equal to the number of successive combustions taking place after the primary combustion at the lower part of the heating flues, the air admissions to the various air expansion chambers being opened or closed periodically in a manner similar to that of the gas admissions into the gas chambers. These improvements in the method of distributing air to the heating flues enable the regulation of temperature at various levels of the side-wall to be effected at any moment.

A method of carrying out these improvements is indicated in Figs. 1 and 2, the former representing a longitudinal vertical section along the line A-B of Fig. 2, while Fig. 2 represents a horizontal section on C-D of Fig. 1. Vertical sections on E-F and G-H are shown in Fig. 3. In these illustrations flues 2 in the side-walls of the ovens 1 receive the gas through openings 3 connected with gas chambers 4, each of which is fed by a distributor. These flues also receive coke oven gas through pipes 10 which are provided with diaphragms.

The heating flues 2 are connected at their lower part through connections 8 with the individual regenerators 6 situated below the ovens, and between which is placed a partition 7 coinciding with the axis of the battery. The various regenerators 6 communicate at their lower part with longitudinal regenerators 9 connected with the chimney by means of flues 12. Underneath the gas chambers the side-walls are prolonged by walls 13 which act as separation walls between the various regenerators 6 of two successive ovens.

At the upper part of each individual regenerator the hot air enters through the openings 8 into the heating flues 2 where it meets the gas rising from the gas chambers 4 through the openings 3. The proportion of gas and the first admission of air is so chosen as to give an incomplete combustion of the gas. The flame rises in each heating flue 2, and it meets at a certain level a secondary admission of air which flows out through the opening 22. The two openings 22 of two adjacent flues 2 are branched on a single auxiliary flue 23, the latter descending in the wall 13, which acts as a separation wall between two distinct regenerators 6, and being connected at its lower part with one of the air expansion chambers 15 which is connected by a tube 17 to the distributor 19.

The regulating member provided on each tube 17 makes it possible to adjust the amount of air admitted into the corresponding air expansion chamber 15 at will, and thus to adjust exactly the flow of secondary air admissions corresponding to one and the same admission of gas through one or the other of the gas chambers 4.

The flame continues its combustion at the upper part of the flue, and enters into the horizontal collecting flue 5, where it receives a third admission of air escaping through an opening 24. This opening 24 is the outlet of an auxiliary flue 25 which descends also in the separation wall 13, and which is connected also with one of the air expansion chambers 14, the lower part of which is connected by a tube 16 to the distributor 18. At each reversal of the gaseous current, the reversing valve of the battery is placed in such a manner as to let the air arrive through the flues into the longitudinal regenerators from which it is distributed into the various individual regenerators and in such a manner as to discharge the products of combustion through the flues.

324,585. PAUL E. VERPEAUX, of Brussels, and UNION CHIMIQUE BELGE SOCIETE ANONYME, a Belgian Limited Company, patentees. Clement Lean, B.Sc., agent, 231, Strand, London, W.C. 2. January 30, 1930.

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## SMELTING ORES.

IN a method of smelting iron and other ores, particularly sulphide ores, in which there are obtained separate layers of metal, matte, and a slag containing less than 15% of iron oxide, the composition of the ore is ascertained and the amount of matte that will be formed from a given charge is calculated; there is then added a sufficient amount of a sulphide having a heat of formation of at least 40 kilogram-calories per gram-atom of sulphur, such as sulphides of aluminium, zinc, manganese, magnesium,

or alkali or alkaline earth metals, or materials such as sulphates and carbon which will produce such sulphides, to raise the mean heat of formation of the matte above 25 kilogram-calories per gram-atom of sulphur, whereupon the charge is smelted with the usual additions. Iron ores containing some manganese may be smelted with the addition of manganese sulphide, yielding a slag containing about 7% of iron oxide and sulphide and containing most of the phosphorus content of the ore, a matter containing about 50% each of manganese and iron sulphides, and a crude pig iron low in manganese. Elements such as arsenic, antimony, nickel, cobalt, molybdenum, and platinum present in iron ores may be taken up in an iron speisse by adding also additional ferriferous material. Lead, silver, and copper ores containing zinc may be smelted in an electric furnace at below 1250° C. to collect the zinc as sulphide in the matte ; or the zinc ore may be smelted in a blast furnace to slag and matte only with the addition of some sodium sulphide or of sodium sulphate and carbon, the matte being then treated with molten iron or speisse to precipitate the lead out of the matte, yielding separate layers of metal, matte, and slag. A lead sulphide ore containing small amounts of other metals may be smelted with calculated amounts of scrap iron, sodium sulphate, coke, and limestone, yielding separate layers of lead, matte consisting mainly of iron sulphide and sulphides of some of the other metals of the ore, and a slag containing 3% of iron oxide. In the application of the process to oxide ores, metals such as iron, chromium, and manganese may be transformed into sulphides by the use of sulphides of calcium, magnesium, or aluminium, and by regulating successive additions of sulphide the metals may be separated successively. Ores of light metals, such as alkali or alkaline earth metals may be treated if there is simultaneously present sufficient heavy metal sulphide.

324,902. H. SKAPPEL, 56, Raadhusgatan, Oslo, Norway.

## FURNACES HEATED WITH COAL SLACK.

As is well known, fine slack is unsuitable for use in ordinary furnace grates. The most effective method in use at the present time for utilising such fuel is that of drying and grinding it to a very fine condition, the fine dust mixed with air being delivered to the combustion chamber through a nozzle and burnt in the manner of a combustible gas mixture. The method has proved satisfactory, but it involves the installation of costly and complicated plant.

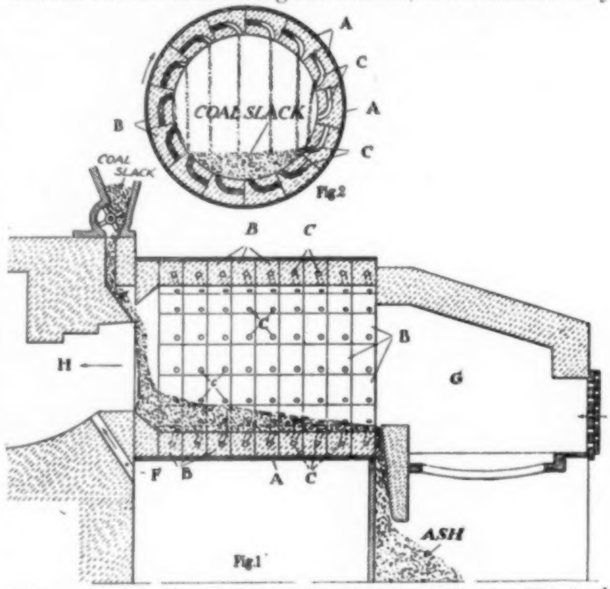
A new device is illustrated in Figs. 1 and 2 and has been designed to enable fine slack to be used advantageously for industrial purposes without the expense of elaborate preliminary treatment. The device comprises the use of a rotary furnace, the interior of which is adapted to carry the fuel around its interior surface and allow it to fall through the furnace interior during which time it is consumed or gasified.

The inner surface of the furnace, which consists of a cylindrical structure lined with refractory material, is shaped to form pockets adapted to carry the fuel round with it during its rotation. The fuel is fed through a rotary regulating valve into one end of the furnace, and it naturally gravitates to the lower part. The rotation of the furnace carries the fuel from the lower to the upper part, and is free to fall back across the interior of the furnace. The size or shape of the pockets carrying the fuel upwards is such that it is not allowed to fall back in a dense mass, but rather to descend like rain so that fine particles are exposed to an adequate quantity of air and are easily burned.

A sectional elevation of this furnace is illustrated in Fig. 1, and consists of a rotary chamber A having pockets C which, at their lower positions, become charged with fuel and discharge this fuel on rotation. The pockets are formed in refractory blocks B which line the rotary chamber, and are shaped to lie in part behind the surface of the blocks.

A cross-section illustrating diagrammatically the shape and position of the pockets relative to the chamber is shown in Fig. 2.

A fixed coal or gas-fired furnace G may be provided for starting and maintaining the combustion or gasification in the rotary furnace, and a fixed combustion and dust-collecting chamber H may be situated at the outlet end, supplementary air being admitted at F. Preheated air may be supplied to the furnace. The pockets C are inclined so that the fuel is fed along the furnace, or the furnace may




rotate on an inclined axis or be of conical shape. The fuel may be gasified by partial combustion in the rotary chamber, combustion being completed in the combustion chamber H or the place where the heat is utilised. The device is applicable to furnaces for steam generation as well as for a wide variety of other industrial purposes.

323,866. Patentee : HENRY A. WEBB, of Swynfold Old Hall, Stourbridge. Agents : Messrs. Marks and Clerk. January 16, 1930.

## IMPROVEMENTS IN THE MANUFACTURE OF HOLLOW METAL.

IN the manufacture of hollow metal rods, bars, etc., from hollow blooms, billets, or ingots, by reducing the heated metal, either by rolling, forging, or drawing the hollow billet with a metal core, introduced prior to the drawing operation, difficulties are frequently experienced. When the metal core is made practically the same length as the billet, the extension of the metal resulting from rolling causes the metal to roll over and form long blank ends. This increases the ending waste. A method of reducing the amount of end waste consists in extending the core beyond the end of the hollow billet and forming an enlarged end of such a shape that the billet, when it lengthens as a result of the reducing operation, is able to pass over the enlarged part without any appreciable resistance to its elongation. The illustration, Fig. 1, shows a section of a hollow billet having such a metal core inserted. The enlarged end is of tapering bulb form which gradually merges into the main part of the core. It will be noted that the enlarged part carries no shoulder or projection likely to catch the billet and subject the core to high tensile stress.

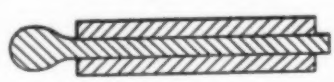


*Fig. 1.*

325,169. ALFRED P. PEHRSON and FREDERICK LLOYD, both of Sheffield, patentees. Messrs. Haseltine, Lake and Co., agents, 28, Southampton Buildings, London. February 13, 1930.

# Business Notes and News

## Steel Works Reorganisation Scheme.

The scheme to be submitted at an extraordinary general meeting of John Brown and Co., Ltd., to be held on the 18th of this month, provides for the reduction of share capital from £5,000,000 to £2,375,000, together with a postponement of the maturity of the debentures until December 31, 1965. Sanction is requested to transfer the Atlas Works of Sheffield and also the works at Scunthorpe to another company or amalgamation as part of a rationalisation scheme in the heavy forgings and castings industry. The calling-up of the outstanding part of the ordinary shares is also included in the scheme.

The chairman of the Company, Lord Aberconway, has stated that proposals have been made for joining in amalgamations with other companies for the purpose of rationalising certain important sections of the Company's business, but no proposal has yet been made to the directors, which, without improvement, would justify them in recommending it for acceptance by the debenture holders and shareholders.

It seems that combination in some form must be achieved in order to curtail reckless competition, and to reduce the cost of maintenance and upkeep of the surplus plant still operating in the country. The position is being actively dealt with in the shipbuilding industry and is being closely investigated by the Directors in other directions.

## Reconstructing an Oil Tanker.

An exceptional performance in ship-repairing and reconstruction has been completed by Palmers' Shipbuilding and Iron Co. The bow and stern ends of the oil tanker *Cadillac*, owned by the Anglo-American Oil Co., were cut off and a new centre section, about 320 ft. in length, built and joined to the smaller sections. This oil tanker is one of the largest of its kind, and it can be appreciated that the work involved considerable initiative, skill, and delicate handling.

The carrying of certain grades of spirit has a considerable influence on the tanks of these vessels, and the carrying service is reduced in consequence. The success of this plan in fitting a new section for the tanks, may solve the difficulty and indicate a more economical method of getting increased service from vessels of this type.

## Steel Sleepers at Home and Abroad.

Certain colonial and overseas railways have used steel sleepers with flat-bottomed rails for many years, and it is curious to note that in tropical districts, where insect pests which destroy wood are prevalent, steel sleepers are actually in use where the line runs through forests of timber suitable for sleeper construction.

As the result of the increasing scarcity of suitable timber, home railway engineers are now carrying out large-scale experiments with sections of railroad equipped with several designs of steel sleeper, made to suit the bull-head rail in use in this country. In one of these designs the trough of the sleeper is not pierced in any way for fixing the chairs. The solid one-piece chairs are electrically welded to the sleeper, so that they cannot work loose, and the fixings are immune from corrosion. No nuts or bolts are used. Another new design for flat-bottomed rails secures many of the same advantages. Both these designs can be supplied in copper-bearing steels, which exhibit a high resistance to corrosion, and have an exceptionally long life. Information respecting these new designs is available from the United Steel Companies, Ltd.

There is no doubt the general adoption of steel sleepers by the railway companies of this country would not only give a welcome fillip to the steel trade, but prove useful to the railways themselves in stimulating some much-needed industrial traffic.

## Electric Power from Pangani Falls.

Negotiations have, we understand, been completed between the Tanganyika Government and the Power Securities Corporation of London for the inauguration of what is regarded as one of the most notable development schemes of the present day in the Empire. Major Conrad Walsh, who is returning to London after the completion of negotiations for the supply of electric power from Pangani Falls, states that big electrification works are to be established. The company undertakes to supply power to townships stretching from the shores of the Indian Ocean to Lakes Victoria Nyanza and Tanganyika.

## Constructional Rights of Terni System.

The Wellman Smith Owen Engineering Corporation, Limited, have recently concluded an important agreement with the Societa Terni, of Terni and Genoa, Italy, relating to the system of open-hearth furnace construction and operation successfully developed at Terni, and with which remarkably good results from the point of view of fuel consumption per ton of steel made have been obtained. Appreciably increased tonnage outputs per furnace have also been made, whilst the capacity of the furnace to produce any desired quality of steel has been fully demonstrated. The Wellman Company have the exclusive constructional rights for Great Britain, the British Dominions, and many other steel-producing countries, and are therefore placed in a position to make the experience of the Terni Company available to their clients. The system involved may be either embodied in existing furnaces or in new furnaces, immaterial of the capacity.

Licences to employ the system have already been let in this country to Messrs. John Lysaght, of Scunthorpe, the Consett Iron Co., Ltd., of Consett, and the Earl of Dudley's Round Oak Works, Brierley Hill, Staffordshire.

## Electric Furnace Company Report.

Referring to the main business of the Electric Furnace Co., Ltd., that of melting-furnaces, the directors' report indicates that the year has been satisfactory, when the general depression in heavy industries is taken into consideration. Rationalisation has been a handicap, but if it ultimately increases prosperity, benefit will accrue. The maintenance of a foreign connection, especially in France, has been an important factor in providing work, and the company is continuing to send British machinery abroad.

Technical progress has been well maintained, and during the year the largest furnaces for brass melting by induction, and steel by high frequency, have either been completed or designed, and their manufacture commenced.

The report makes special reference to the great activity and increase in scope of operations of the subsidiary company, the Electric Resistance Furnace Co., Ltd.

## Grimesthorpe Foundry.

The English Steel Corporation, Ltd., it is stated, have now concentrated most of their steel-castings work at Grimesthorpe Foundry, formerly connected with Cammell Laird and Co., Ltd. The foundry is laid out for the weekly production of about 200 tons of castings. It is producing all kinds of carbon steel, manganese steel, nickel-chrome, and chrome-steel castings. In manganese steel the foundry specialises in liner plates, rock-crushing machinery, details, cams, tappets, and rolls. Large quantities of castings are being turned out for dredger work, such as buckets, tread and cheek plates, top and bottom tumblers, etc.

The smallest casting produced so far weighed about 7 lb. The largest, in the "as cast" condition, weighed 140 tons, reduced to 95 tons after being machined; this was an anvil block for a five-ton Massey friction drop stamp.

## Metallising Wood.

A new process has recently been developed in Germany by which the pores of wood can be filled with metal. The process is carried out by plunging wood, either in its natural or in a prepared state, into molten metal and keeping it under pressure while submerged. The degree of filtration of the wood by the metal is dependent upon the duration of treatment, the temperature, and the pressure. In favourable circumstances the whole of the cellular tissues are filled in addition to the interstices of the fibres. All parts that are not filled by the metal remain unchanged.

The material can be machined like ordinary wood, and does not increase in volume through absorbing moisture. The wood treated with metal has a peculiar appearance, and is likely to lend itself to artistic use and interior architectural purposes.

## Continental Licences of Wild-Barfield Furnaces.

Owing to the continued expansion in business and increased demand for Wild-Barfield Electric furnaces the licences for France, Switzerland, and the Netherlands, La Compagnie Francaise "Wild-Barfield" have recently taken extensive new premises at 110, Avenue du General Mickel Bizot, Paris. A full range of these furnaces is obtainable.

# Some Contracts.

A substantial order for hematite iron has been secured by Messrs. Pease and Partners. The contract, it is understood, is for 200,000 tons delivered to the Sheffield district over the next five years. The terms are stated to be on a sliding-scale arrangement. The iron will be supplied from the firm's Middlesbrough works.

The West Midlands Joint Electricity Authority have awarded the contract for the coal-handling plant for the new Ironbridge Power Station to the Mitchell Conveyor and Transporter Co., Ltd., Atlantic House, Holborn Viaduct, E.C. 1. The plant consists generally of "Mitchell" patent side-discharge weighing-type tipplers for unloading colliery wagons up to 20 tons capacity, and a series of "Mitchell" ball-bearing type belt conveyers for placing the coal into the boiler-house bunkers or into store. The plant also includes a travelling store bridge, spanning the coal store, fitted with two special-type elevators for reclaiming coal from store. The ultimate capacity of the store yard will be over 80,000 tons.

Babcock and Wilcox, London, have received an order from the Calcutta Electric Supply Corporation for four C.T.M.-type water-tube boilers, each capable of evaporating 50,000 lb. of water per hour, for installation at their Cossipore Station, Calcutta. The contract includes superheaters, economisers, steel chimneys, and pipework, all of which will be made at the company's works at Renfrew, Scotland.

Workman, Clark and Co., Belfast, have secured a contract for a whale-oil factory ship similar in design and equipment to the *Kosmos*, which was launched a year ago by the same firm. The *Kosmos* has a tonnage of 17,800, and is 550 ft. long.

Staveley Coal and Iron Co., Derbyshire, have booked orders for 770 tons of cast-iron pipes for Salford Corporation Gas Department, 650 tons for Leicester Corporation Gas Department, 320 tons for Birmingham, and 253 tons for Harrogate.

Dorman, Long and Co., Middlesbrough, have secured an order for 13,500 tons of steel rails and fish-plates for the Union of South Africa.

The Bengal-Nagpur Railway have placed contracts with Beyer, Peacock and Co., Manchester, for twelve F-type locomotive boilers to the value of £19,000.

General Refractories, Ltd., of Sheffield, have received an order from New Zealand for their new high alumina firebrick, the "Dreadnought," for use in connection with oil-fired furnaces. The production of these bricks opens out new avenues for export trade, and proves that there is a market abroad for a really super-quality firebrick.

Charles Richards and Sons, Wednesbury, have received orders from the South African Railways for 4,201,000 gauge-clips and 1,269,000 "T" head bolts and nuts; from the Buenos Aires Great Southern Railway for mild steel rivets, and from the Central Argentine Railway for washers.

A contract for press equipment has been awarded to Messrs. Davy Bros., Sheffield, in connection with the new manufacturing plant to be constructed at Welwyn Garden City for the Norton Grinding Wheel Co.

The tender (£29,825) of John Thompson Water Tube Boilers, Ltd., Wolverhampton, for three water-tube boilers, including economisers, pre-heater, piping, feed pumps, and ash-handling plant, has been accepted by the Metropolitan Water Board.

Standard Telephones and Cables, Ltd., London, have been awarded a contract (£42,000) by the London County Council for high- and low-tension electric cables and the building-up of existing cables for the tramway service.

The Buenos Aires Great Southern Railway have placed an order (£11,000) with Independent Sprinklers, Ltd., London, for sprinklers and hydrant installations and electric automatic pumping sets.

The Department of Posts and Telegraphs, Wellington, New Zealand, have placed an order for 50 miles of tinned-annealed copper wire with the Hackbridge Cable Co., Walton-on-Thames.

The Underground Electric Railways Co. of London, Ltd., have placed provisional orders for the construction of 62 new cars for the L.M.S. and Bakerloo joint service between Elephant and Castle and Watford stations. The bodies will be built by the Metropolitan-Cammell Carriage, Wagon and Finance Co., Ltd; the electrical equipment by the British Thomson-Houston Co., Ltd.; and the motors by the General Electric Co., Ltd.

The London Midland and Scottish Railway Co. have ordered from Greenwood and Batley, Ltd., Albion Works, Leeds, eight industrial electric trucks, flat platform type, equipped with D.P. batteries, for dealing with luggage at the new landing stage at Tilbury.

The London County Council Highways Committee have accepted the tender of James Keith and Blackman Co., Ltd., of Farringdon Avenue, E.C. 4, for the supply and erection of four exhaust fans and motors for No. 1 ventilating shaft of Blackwall Tunnel. In connection also with the ventilation of this tunnel the Tees Side Bridge and Engineering Works, Ltd., of Middlesbrough, have secured the contract for the supply and erection of steel girder supports.

The Anglo-Russian Trading Delegation have placed orders with Associated British Machine Tools Makers, Ltd., London, and other firms for machine tools to the value of £150,000. Metropolitan-Vickers, Ltd., Manchester, are supplying the whole of the electrical equipment for a power station at Zuevka to the value of £300,000. A general agreement was reached recently whereby orders to the value of £3,000,000 will be placed by the Trade Delegation with the Metropolitan-Vickers Co. An order for special high-speed steel to the value of £50,000 has been placed with Saville and Co., Sheffield.

The Central Electricity Board announce that it has placed contracts, amounting approximately to £326,000, for works in connection with various schemes, including:—For transformers in the areas of the North-West England and North Wales and Mid-East England schemes, with the British Thomson-Houston Co., London; Brush Electrical Engineering Co., Loughborough; the English Electric Co., Stafford; Ferranti, Hollinwood; and C. A. Parsons and Co., Newcastle-on-Tyne. For oil-filtering and storage equipment for outdoor transforming stations in the area of the Central England scheme, with Super-Centrifugal Engineers, London.

Nine British and Continental firms have presented tenders for the construction of the bridge at Benha, in Lower Egypt. The lowest offer is that of Dorman Long and Co., at £E166,732, and the highest that of Messrs. Humbolt at £E405,267. Other tenders were submitted by Messrs. Savigliano, £E170,452; Baumemarpent, £E171,508; and the Cleveland Bridge and Engineering Co., £E186,645.

The Clyde Shipping Co., Ltd., Glasgow, have placed a contract with David and William Henderson and Co., Glasgow, for a high-class passenger, cargo, and cattle-carrying steamer. The builders will supply triple-expansion engines having cylinders 21 in., 34 in., and 56 in. diameter, and 39 in. stroke.

The Woodall-Duckham Vertical Retort and Oven Construction Co. (1920), Ltd., has received an order from the Rhyl Urban District Council for an installation of continuous vertical retorts with a total carbonising capacity of 40 tons a day. The contract includes coal-handling plant and coal store, steam-engine driven lift, and coke storage hoppers. The company has also received an order from the Newquay (Cornwall) Gas Co. for an installation having a total daily carbonising capacity of 13 tons, and an order from the Lincoln Corporation Gas Department for a tar-treatment plant with a normal capacity of 10 tons of crude tar per 24 hours.

The English Electric Co. has received orders for 12 electric trolley 'buses for the Bradford Corporation, and six for the Notts. and Derbyshire Traction Co. The 'buses will be built at the firm's Preston works.

## IRON AND STEEL REPORT.

By far the most important development in the iron and steel trades during the past month, not merely from the point of view of Lancashire alone but nationally also, has been the large-scale rationalisation scheme affecting the most important concerns in the iron, steel, and coal industries of Lancashire. Two huge undertakings are to be set up—the Lancashire Steel Corporation, with a nominal capital of £5,750,000, and the Wigan Coal Corporation, with a capital of £1,746,555, and debentures to the value of £500,000. Six concerns are to be brought into the mergers—the Partington Steel and Iron Co., the Pearson and Knowles Coal and Iron Co., Rylands Bros., the Wigan Coal and Iron Co., the Wigan Junction Colliery Co., and the Moss Hall Coal Co. Altogether 16 collieries, including one in Nottinghamshire, will be included in the Wigan Coal Corporation, the total annual output being in the neighbourhood of 3,300,000 tons. The potential economies from the colliery venture are too obvious to need stressing here. On the steel side, a good slice of the new capital which is to be raised is to be employed in the construction of new iron and steel-producing plant at Irlam, on the Manchester Ship Canal, a position which, it is anticipated, will result in important advantages in connection with trade with overseas markets. The Securities Management Trust, an offshoot of the Bank of England, is showing a practical interest in the project by furnishing new capital to the extent of £500,000.

In the foundry-iron market, contrary to recent expectations on the part of consumers, Midland makers have refused to make any price concessions, and the opinion now is that they are likely to continue to do so, their view being that production costs for virtually all producers do not justify reductions. Irrespective of the price question, however, few foundries are in a position from the point of view of order-books to enter into extensive forward contracts, and buying for about a month ahead is the general rule Under the circumstances stocks of iron are mounting at the blast-furnaces, in spite of the fact that many have been damped down. A few of the more fortunately situated producers are able to dispose of a good proportion of their make in pipe foundries or other associated undertakings. So far as iron prices generally are concerned, there has been a slight grading in the case of Scottish makes and also in hematite iron, but otherwise quotations have been maintained at the levels current a month ago.

In the finished iron section there has been a moderate demand experienced for marked bars, but common bars meet with a very poor market, and makers of these seem to be resigned to a permanently restricted trade due largely to the competition of steel, although competition from the appreciably cheaper Continental material is also a potent factor in the situation. Lancashire bar makers during the past month have brought down crown-quality bars by 10s. a ton to £10 5s., whilst second-grade bars are roughly £1 cheaper at about £8 15s. per ton.

There has been no perceptible improvement in the demand for steel, although certain of the shipbuilding areas, notably the Clyde with its certainty of work on the new mammoth Cunarder when details are settled, are anticipating better times. There should be a spurt in the demand for steel materials from this direction, but, unfortunately, the normally important outlet in constructional engineering in most of the leading centres shows little indication of recovery. Lancashire is probably one of the worst sufferers in this respect. Locomotive builders are taking fair quantities, as also are certain speciality branches of engineering. Boiler makers, textile machinists, and the majority of general engineers, however, are affording relatively little support to the steel market just now. Apart from small rerolled bars, there has been no quotable change on balance in the general price position. Rerollers, for the second time within a few months, have reduced values by half a crown, current rates ranging from £7 17s. 6d. to £8 per ton, according to quantity.

## CLEVELAND FOUNDRY CONVENTION.

The annual convention and accompanying exhibition of the American Foundrymen's Association, held at Cleveland, was a very successful effort. The attendance was considerable greater than its predecessors and established a record. The technical sessions held throughout the week attracted an unusually large number of foundrymen and those directly interested in foundry work, and considerable discussion arose from the subjects chosen for presentation in the form of papers. In addition to papers, sessions were allocated to shop-operation courses, which created a good deal of discussion, and the exchange of ideas resulting from the discussion of many practical problems is bound to increase the outlook of the foundryman.

Of the papers presented at the Convention mention may be made of a few. The effects of prolonged heating at elevated temperatures was described by R. S. McPherran in a paper of which he was joint author with R. H. Krueger. The conclusion arrived at, as a result of their consideration of the subject, indicated that high-silicon materially accelerates the decomposition of the pearlite. Nickel does the same, although not to the same extent. Chromium increases tensile strength at room temperatures and delays decomposition of pearlite, and it also maintains strength at high temperatures.

"The Continuous Melting of Metal in an Electric Furnace for Use in a Stove-plate Foundry," presented by N. L. Turner, caused considerable discussion. This can be understood when it is realised that the author claims not to have used pig-iron for the last two years and yet produces a quality of iron higher than under former conditions. H. M. Lane mentioned an instance of iron being melted in a similar manner, and castings produced at very low cost. The results from an elaborate series of experiments, to determine the volume changes in metals and alloys after casting, were given by E. J. Ash.

An interesting feature of these foundrymen's conventions is the exchange papers which are presented. The Institute of British Foundrymen was represented by J. G. Pearce, of the British Cast-iron Research Association, whose paper on "The Correlation of Mechanical Tests for Cast Iron" caused much discussion. The author emphasised the necessity for the use of standard bars and methods of tests in order to correlate mechanical tests and proper comparisons.

L. F. C. Girardet presented a paper, on behalf of the Association Technique de Foundrie, entitled "Simplified Methods for Controlling the Production of Cast Iron." The use of the shear test was advocated by the author. He suggested the casting of conical buttons as specimens attached to the casting, which, he claimed, are suitable for inspection by the fracture method or examination under the microscope.

The session on malleable cast iron included a paper by H. A. Schwartz on "Factors Affecting the Machinability of Malleable Cast Iron." In a written discussion on the paper, L. M. Jasper stated his belief that high-carbon, low-strength malleable iron machined much better than low-carbon, high-strength iron. This was taken up by Enrique Touceda, who believed that high or low carbon in malleable cast iron had little or no effect on machinability, and that the effect of silicon was more important than carbon, particularly in the high-carbon irons which have a tendency towards primary graphitisation.

The exhibition of foundry equipment was more complete than in previous years, and many interesting features proved very attractive. Two complete foundry units were shown in operation, providing a unique demonstration of casting production on modern lines. Grey iron was melted in an electric furnace and cast into previously prepared moulds; the castings being subsequently cleared, the sand reconditioned and returned for further use in preparing the moulds. The whole process was effectively carried out and added considerable interest to the exhibition. In addition, practically all the exhibitors had their equipment in operation.

# MARKET PRICES

## ALUMINIUM.

| | | |
|---|---|---|
| 99% Purity | | £95 0 0 |
| Castings, 2.L5 Alloy | lb. | 1/3–1/8 |
| „ 2.L8 „ | „ | 1/4–1/9 |
| „ Silicon „ | „ | — |

## ANTIMONY.

| | |
|---|---|
| English | £40 0 0 |
| Chinese | 27 5 0 |
| Crude | 20 0 0 |

## BRASS.

| | | |
|---|---|---|
| Solid Drawn Tubes | lb. | 11d. |
| Brazed Tubes | lb. | 12¾d. |
| Rods Drawn | „ | 10⅝d. |
| Wire | „ | 9¾d. |
| *Extruded Brass Bars | „ | 6d. |

## COPPER.

| | | |
|---|---|---|
| Standard Cash | | £53 15 0 |
| Electrolytic | | 60 10 0 |
| Best Selected | | 60 0 0 |
| Tough | | 59 10 0 |
| Sheets | | 87 0 0 |
| Wire Bars | | 61 7 6 |
| Ingot Bars | | 61 7 6 |
| Solid Drawn Tubes | lb. | 12¼d. |
| Brazed Tubes | „ | 12½d. |

## FERRO ALLOYS.

| | | |
|---|---|---|
| ‡Tungsten Metal Powder | lb. | £0 3 1 |
| ‡Ferro Tungsten | „ | 0 2 10 |
| §Ferro Chrome, 60-70% Chr. Basis 60% Chr. 2-ton lots or up. | | |
| 2-4% Carbon, scale 11/- per unit | ton | 30 15 0 |
| 4-6% Carbon, scale 7/- per unit | „ | 23 7 6 |
| 6-8% Carbon, scale 7/- per unit | „ | 22 12 6 |
| 8-10% Carbon, scale 7/- per unit | „ | 22 0 0 |
| §Ferro Chrome, Specially Refined, broken in small pieces for Crucible Steelwork. Quantities of 1 ton or over. Basis 60% Ch. Guar. max. 2% Carbon, scale 10/- per unit | „ | 33 12 6 |
| §Guar. max. 1% Carbon, scale 13/6 per unit | „ | 38 2 6 |
| §Guar. max. 0.7% Carbon, scale 15/- per)unit | „ | 39 15 0 |
| ‡Manganese Metal 96-98% Mn. | lb. | 0 1 3 |
| ‡Metallic Chromium | „ | 0 2 7 |
| §Ferro-Vanadium 25-50% | „ | 0 12 9 |
| §Spiegel, 18-20% | ton | 7 5 0 |
| Ferro Silicon— | | |
| Basis 10%, scale 3/- per unit | ton | 5 17 6 |
| ‖20/30% basis 25%, scale 3/- per unit | „ | 7 0 0 |
| ‖45/50% basis 45%, scale 5/- per unit | „ | 10 17 6 |
| ‖70/80% basis 75%, scale 6/- per unit | „ | 17 10 0 |
| ‖90/95% basis 90%, scale 10/- per unit | „ | 25 6 0 |
| §Silico Manganese 65/75% Mn., basis 65% Mn. | „ | 14 0 0 |
| §Ferro-Carbon Titanium, 15/18% Ti | lb. | 0 0 6 |
| §Ferro Phosphorus, 20-25% | ton | 16 0 0 |

## FUELS.

| | |
|---|---|
| Foundry Coke— | |
| S. Wales Export | £1 10 0 to £1 17 0 |
| Sheffield „ | 0 19 6 „ 1 0 0 |
| Durham | 1 6 0 to 1 9 0 |
| Furnace Coke— | |
| Sheffield Export | £0 19 6 to £1 0 0 |
| S. Wales „ | 1 5 0 to 1 7 6 |
| Blast-Furnace Coke, at ovens | 0 15 6 |

## GUN METAL.

| | | |
|---|---|---|
| Commercial Ingots | | £71 0 0 |
| *Gunmetal Bars, Tank brand, 1 in. dia. and upwards | lb. | 0 1 0 |
| *Cored Bars | „ | 0 1 2 |

## LEAD.

| | |
|---|---|
| Soft Foreign | £18 0 0 |
| English | 19 10 0 |

## MANUFACTURED IRON.

| | |
|---|---|
| Scotland— | |
| Crown Bars | £10 5 0 |
| N.E. Coast— | |
| Rivets | 11 10 0 |
| Best Bars | 11 5 0 |
| Common Bars | 10 15 0 |
| Lancashire— | |
| Crown Bars | 10 15 0 |
| Hoops | 13 0 0 |
| Midlands— | |
| Crown Bars | 10 7 6 |
| Marked Bars | 12 10 0 |
| Unmarked Bars | — |
| Nut and Bolt Bars | 9 2 6 |
| Gas Strip | 11 2 6 |
| S. Yorks.— | |
| Best Bars | 11 10 0 |
| Hoops | 12 0 0 |

## PHOSPHOR BRONZE.

| | | |
|---|---|---|
| *Bars, Tank brand, 1 in. dia. and upwards | lb. | 1/- |
| *Cored Bars | „ | 1/2 |
| †Strip | „ | 1/2 |
| †Sheet to 10 W.G. | „ | 1/3 |
| †Wire | „ | 1/3¼ |
| †Rods | „ | 1/2½ |
| †Tubes | „ | 1/6½ |
| †Castings | „ | 1/2 |

†10% Phos. Cop. £35 above B.S.
†15% Phos. Cop. £40 above B.S.
†Phos. Tin (5%) £30 above English Ingots.

## PIG IRON.

| | |
|---|---|
| Scotland— | |
| Hematite M/Nos. | £4 1 0 |
| Foundry No. 1 | 4 0 6 |
| „ No. 3 | 3 18 0 |
| N.E. Coast— | |
| Hematite No. 1 | 3 14 6 |
| Foundry No. 1 | 3 10 0 |
| „ No. 3 | 3 7 6 |
| „ No. 4 | 3 6 6 |
| Cleveland— | |
| Foundry No. 3 | 3 7 6 |
| „ No. 4 | 3 6 6 |
| Silicon Iron | 3 15 0 |
| Forge No. 4 | 3 6 0 |
| N.W. Coast— | |
| Hematite | 4 10 6 |
| Midlands— | |
| N. Staffs Forge No. 4 | 3 15 6 |
| „ Foundry No. 3 | 3 19 6 |
| Northants— | |
| Forge No. 4 | 3 11 0 |
| Foundry No. 3 | 3 15 0 |
| Derbyshire Forge | 3 14 6 |
| „ Foundry No. 3 | 3 18 6 |
| West Coast Hematite | 4 10 0 |
| East „ „ | 4 9 0 |

## SWEDISH CHARCOAL IRON AND STEEL.

| | |
|---|---|
| Pig Iron | £6 0 0 to £7 10 0 |
| Bars, hammered, basis | £17 10 0 „ £18 10 0 |
| Blooms | £10 0 0 „ £12 0 0 |
| Keg steel | £32 0 0 „ £33 0 0 |
| Faggot steel | £20 0 0 „ £24 0 0 |

All per English ton, f.o.b. Gothenburg.

## SCRAP METAL.

| | |
|---|---|
| Copper Clean | £47 0 0 |
| „ Braziery | 44 0 0 |
| „ Wire | — |
| Brass | 35 0 0 |
| Gun Metal | 43 0 0 |
| Zinc | 9 0 0 |
| Aluminium Cuttings | 63 0 0 |
| Lead | 15 10 0 |
| Heavy Steel— | |
| S. Wales | 3 0 0 |
| Scotland | 2 15 0 |
| Cleveland | 2 12 6 |
| Cast Iron— | |
| Lancashire | 3 2 6 |
| S. Wales | 2 18 0 |
| Cleveland | 3 0 0 |
| Steel Turnings— | |
| Cleveland | 2 8 0 |
| Lancashire | 1 15 0 |
| Cast Iron Borings— | |
| Cleveland | 2 2 6 |
| Scotland | 2 8 0 |

## SPELTER.

| | |
|---|---|
| G.O.B. Official | — |
| Hard | £14 5 0 |
| English | 17 5 0 |
| India | 15 10 0 |
| Re-melted | 16 0 0 |

## STEEL.

| | | |
|---|---|---|
| Ship Plates (Scotland) | | £8 15 0 |
| „ „ (N.E. Coast) | | 8 15 0 |
| Boiler Plates (Land), Scotland | | 10 0 0 |
| „ „ (Marine) „ | | 10 10 0 |
| Sheets 20 W.G. (Scotland) | | 10 0 0 |
| „ „ (Land), N.E. Coast | | 10 0 0 |
| „ „ (Marine) „ „ | | 10 10 0 |
| Angles (Scotland) | | 8 7 6 |
| „ (N.E. Coast) | | 8 7 6 |
| „ (Midlands) | | 8 7 6 |
| Joists | | 8 10 0 |
| Heavy Rails | | 8 10 0 |
| Fish-Plates | | 12 0 0 |
| Light Rails | | 8 17 6 |
| Sheffield— | | |
| Siemens Acid Billets | | 9 10 0 |
| Hard Basic | | 9 12 6 |
| Medium Basic | | 8 2 6 |
| Soft Basic | | 6 10 0 |
| Hoops | | 9 15 0 |
| Manchester— | | |
| Hoops | | 10 0 0 |
| Bridge and Tank Plates | | 8 17 6 |
| Angles | | 8 7 6 |
| Tool Steel, High Speed— | | |
| Finished Bars 18% Tungsten | lb. | 3/- |
| Round and Squares, ½ in. to ¼ in. | „ | 3d. |
| Under ¼ in. to 3/16 in. | „ | 1/- |
| Round and Squares 3 in. | „ | 4d. |
| Flats under 1 in. × ½ in. | „ | 3d. |
| „ „ ½ in. × ¼ in. | „ | 3d. |

## TIN.

| | |
|---|---|
| Standard Cash | £142 0 0 |
| English | 142 10 0 |
| Australian | 142 10 0 |
| Eastern | 145 2 6 |
| Tin Plates I.C. 20 × 14 box | 18/3 |
| Block Tin Cash | £143 5 0 |

## ZINC.

| | |
|---|---|
| English Sheets | £27 0 0 |
| Rods | 30 0 0 |
| Battery Plates | 24 10 0 |

* McKechnie Brothers, Ltd., quoted June 5. † C. Clifford & Son, Ltd., quoted June 5. ‡ Murex Limited.

Pearson & Knowles' Current Basis Prices:—Wrought Iron Bars, £10 15s. 0d.; Mild Steel Bars, £8 0s. 0d. to £8 7s. 6d.; Wrought Iron Hoops, £12; Best Special Steel Baling Hoops, £9 15s. 0d.; Soft Steel Hoops (Coopers' and Ordinary Qualities), £9 to £9 5s. 0d.; C.R. & C.A. Steel Hoops, £12 10s. 0d. to £13 10s. 0d.; "Iris" Bars, £9 15s. 0d. All Nett Cash.

‖R. Hostombe, quoted June 5. Delivery c.i.f., suitable U.K. ports. § Prices quoted June 5, ex warehouse.